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Quantico, Virginia 22134-5068*

MASTER OF MILITARY STUDIES

**STRATEGIC AND OPERATIONAL RELEVANCE OF HEAVY LIFT IN THE UNITED
STATES MARINE CORPS: CH-53E PROGRAM**

**SUBMITTED IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE DEGREE OF
MASTER OF MILITARY STUDIES**

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Academic Year 2001-2002

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REPORT DOCUMENTATION PAGE				Form Approved OMB No. 0704-0188	
Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing this collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden to Department of Defense, Washington Headquarters Services, Directorate for Information Operations and Reports (0704-0188), 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to any penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number. PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ADDRESS.					
1. REPORT DATE (DD-MM-YYYY) 01-07-2002		2. REPORT TYPE Master's thesis		3. DATES COVERED (FROM - TO) xx-xx-2001 to xx-xx-2002	
4. TITLE AND SUBTITLE Strategic and Operational Relevance of Heavy Lift in the United States Marine Corps: CH-53E Program Unclassified				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S) McLellan, Archibald M. ;				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME AND ADDRESS USMC Command and Staff College Marine Corps University, MCCDC 2076 South Street Quantico, VA22134-5068				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME AND ADDRESS USMC Command and Staff College Marine Corps University 2076 South Street, MCCDC Quantico, VA22134-5068				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT APUBLIC RELEASE					
13. SUPPLEMENTARY NOTES					
14. ABSTRACT See report.					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:		17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19. NAME OF RESPONSIBLE PERSON	
		Public Release	64	EM114, (blank) lfenster@dtic.mil	
a. REPORT Unclassified	b. ABSTRACT Unclassified	c. THIS PAGE Unclassified		19b. TELEPHONE NUMBER International Area Code Area Code Telephone Number 703767-9007 DSN 427-9007	
				Standard Form 298 (Rev. 8-98) Prescribed by ANSI Std Z39.18	

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EXECUTIVE SUMMARY

Title: STRATEGIC AND OPERATIONAL RELEVANCE OF HEAVY LIFT IN THE UNITED STATES MARINE CORPS: CH-53E PROGRAM

Author: Major Archibald M. McLellan, United States Marine Corps

Thesis: This essay examines the strategic and operational relevance of the heavy lift capability in the United States Marine Corps.

The only way to truly realize the full potential of Expeditionary Maneuver Warfare (EMW) and the capabilities of the MV-22, is to maintain the existing synergistic relationship between the medium and heavy lift aircraft working together to accomplish the mission.

In current future plans the MV-22 will be required to carry external loads for 48 percent of its sorties in the movement of a Regimental Landing Team (RLT). This minimizes the speed advantage of the MV-22, as the limitations inherent with external loads (increased drag, load instability and integrity), prevent taking most external loads out toward the maximum speed of the MV-22. Accordingly, the best alternative to ensuring that we preserve the MV-22 speed advantage is to ensure there are adequate numbers of CH-53E helicopters to perform all the majority of external lift missions.

If the Marine Corps changed the current ratio of medium lift to heavy lift aircraft from 3:1 to 2:1 i.e. by adding two CH-53E's to the current MEU, increasing the number of CH-53E's (to six) we would see a 20 percent reduction in total waves and a 22 percent decrease in time required to accomplish a reinforced Company movement.

In the future changing the force ratio from 2:1 to 1:1 (medium to heavy), the CH-53E (SLEP) has the potential to provide a significant improvement in the ability to move the force. There is the potential for a 28 percent decrease in sorties required to accomplish a Regimental Landing Team movement by air and an overall timesaving of 29 percent in addition to the already realized savings of 25 percent from balancing the force with today's CH-53E.

The projected force structure will not be capable of supporting the concepts of Expeditionary Maneuver Warfare, STOM and OMFTS without 100 percent utilization of all of the CH-53E assets forecast to be in the inventory. The projected force structure has slated to remove the CH-53E from the reserves and decrease the total number to 111. There will not be enough CH-53E helicopters to accomplish the anticipated heavy lift mission sin the future.

A modernized CH-53 will be able to accomplish 3.3 MV-22 sorties for every CH-53 sortie. This ability to reduce total sorties is truly a force multiplier, as any savings in sorties has a direct correlation on survivability of the aircraft and equipment due to less exposure.

The cost of the SLEP is one-fifth the cost of a replacement aircraft. Operationally it is the most cost effective way to support Expeditionary Maneuver Warfare. The reductions in operations and support cost reduce the flight hour cost by 25 percent of the current cost while providing nearly three times the capability.

INTRODUCTION

This paper will address three topics regarding the strategic and operational relevance of heavy lift in the United States Marine Corps. The topics are the history of heavy lift, its current and future requirements, and the Service Life Extension Program (SLEP) or modernization program. The future requirements will help to identify the capabilities of the eventual replacement of the CH-53E, the premier heavy lift helicopter in the Department of Defense (DoD).

This paper will discuss the relevance of heavy lift helicopters by determining the initial requirements for heavy lift helicopters in the 1960's and how they were met. There are several relevant contingency case studies highlighting the continuing relevance of the CH-53E and the flexibility it brings to the joint force or combatant commander.

The Department of the Navy (DoN) is faced with difficult decisions due to competing priorities for limited fiscal resources (see figure 1). This paper will provide the justification for why the DoN must not only fund the CH-53E SLEP but must procure more heavy lift aircraft (see figure 2). The current requirements in the form of tactical mobility will not be reduced with the successful introduction of the MV-22 to the operating forces but will actually increase. While futurists predict the forces of tomorrow are getting lighter, the truth is they are getting heavier; therefore, the requirement for heavy lift will continue to increase in the future. Finally, with a look toward the future, I will propose a force structure change that offers the ability to truly task organize within the aviation community to realize the full potential of both the MV-22 and Effects Based Operations.¹

¹ Effects Based Operations is defined as not being concerned with the individual platform or service that accomplishes the mission but rather the capability to achieve the desired end state.

CHAPTER 1

HISTORY OF UNITED STATES MARINE CORPS HEAVY LIFT

*In practice we always base our preparations against an enemy
on the assumption that his plans are good; indeed, it is right to rest
our hopes not on a belief in his blunders, but on the soundness of our provisions.
Nor ought we believe that there is much difference between man and man,
But to think that superiority lies with him who is reared in the severest school.*

-- Archidamus²
Spartan King

The requirement to carry heavy tactical and logistic equipment dates back to the beginning of warfare. An army's ability to carry its own equipment and supplies has been the military's Achilles' heel from before Napoleon to current day. The applicability of the helicopter to meet this requirement dates back to the mid 1940's. By the end of WWII there were over 400 helicopters in service performing mostly utility and rescue missions. As the Korean War began, the heavy lift requirement again came to the forefront with the need to transport large amounts of over-sized equipment to and from austere locations in the mountainous regions of Korea. There were significant technological improvements and refinements, but the desire to fully exploit vertical lift could best be characterized as "low key."³

In May of 1965 a Russian helicopter lifted 55,347 pounds to an altitude of 9,318 feet.⁴ Coincidentally, 1965 was the first year the U.S. Navy identified the requirement for the Heavy Lift Helicopter (HLH). The requirement was derived from concerns on the delays involved in moving unflyable aircraft to repair facilities. In early 1966 the Marine Corps identified an urgent requirement to retrieve downed aircraft and to possess the ability to move heavy, essential combat equipment, which exceeded the capability of current helicopters. Two of

² Thucydides. Edited by Strassler, Robert B. *The Landmark Thucydides. A Comprehensive Guide to the Peloponnesian War*, (New York: The Free Press, 1996).

³ CH-53E Program History, N.P., N.D. Received from APW-51, Major John Celigoy, 1.

⁴ Sikorsky Aircraft H-53E Program History, 1987, 6.

the driving factors in this requirement were the assignment of the existing CH-53 to combat operations in Vietnam in 1967 and the inability to move a battle-damaged or otherwise unflyable aircraft to a safe location for repairs.⁵

One of the first requirements documents for the Department of the Navy was the Specific Operational Requirements 14-20: Heavy Lift Helicopter (HLH) (SOR: 14-20) dated 24 October 1967. This document established the initial missions and requirements that would eventually lead to the development of the modern CH-53E program. Some of the specifics of the document follow:

Missions	<ul style="list-style-type: none">• Logistics Resupply• Support of Construction Requirements• Tactical Movement of Combat Equipment• Recovery of Damaged Equipment• Removal of Unflyable Aircraft
Requirements	<ul style="list-style-type: none">• Payload 18 tons• Operationally compatible with Carrier and Amphibious Assault Ships• Operational requirement to be filled 1970-1980 time period
Programmatics	<ul style="list-style-type: none">• OPEVAL FY-70• RDT&E Est 24.9M• Production estimate 40 Aircraft

On 24 April 1969 the Chief of Naval Operations briefed the Senate Armed Services Committee on the Navy/Marine HLH requirements and stressed the development was required before the CH-53D's would need to be overhauled. The Navy and Marine Corps wanted to ensure that the ability to transport the aircraft remained high on the priority list either by amphibious shipping or strategic air lift (C-5). The fact they were taking proven concepts and expanding on them meant that it was limited risk procurement. The ability of

⁵ CH-53E Program History, N.P., N.D. Received from APW-51, Major John Celigoy, 3.

the CH-53E to lift three times the amount the CH-53D carried meant a significant increase in the tactical and logistical capability of the of the forces employing the aircraft.⁶

On the 21st of September 1970 Under-Secretary of Defense David Packard stated in a letter to the Chairman of the Senate Appropriations Committee:

The Army and the Navy have essentially the same tactical equipment to move and the standard shipping container is becoming the major discrete logistics load. It has been shown that a Heavy Lift Helicopter sized to offload containers from ships can accommodate most tactical equipment with a high degree of assurance and can be based aboard the Marine Corps LHA amphibious carriers. For these reasons I have approved the development of the single Heavy Lift Helicopter for use by all Services requiring such an aircraft.⁷

In October of 1970 Brigadier General Keith B. McCutcheon, the Commanding General III Marine Amphibious Force, outlined to the Commandant of the Marine Corps the urgent requirement for greatly improved vertical lift for our heavy logistic and assault support helicopters. He outlined the requirement in vivid terms of specific losses of aircraft, heavy artillery, and other invaluable combat equipment that was either lost or destroyed in Vietnam due to the lack of adequate lift capabilities. In every case, the equipment he cited could have been recovered with an aircraft with the capabilities of the CH-53E.

Combat operations in Vietnam were replete with examples for the heavy lift requirement. In one case, the Army accepted a mission to retrieve two Marine artillery pieces because weather had made the roads impassible. There were competing priorities, and the Army helicopters where required to accomplish Army missions and arrived for the mission. Fortunately, the following day, Marine CH-53D's were able to lift the artillery pieces in the morning when the cooler temperatures provided better ambient environmental conditions for optimal hover performance. The lack of a heavy lift capability required an

⁶ CH-53E Program History, N.P., N.D. Received from APW-51, Major John Celigoy, 3.

⁷ Brief to the Armed Services Committee, N.P., N.D., received from PMA-261, Colonel Croisietiere.

operational delay that in turn required Marines to guard the artillery pieces in contested territory throughout the night.

While forwarding General McCutcheon's 1970 comments regarding the shortage of a heavy lift capability, the Commanding General, Fleet Marine Forces Pacific, described the heavy lift helicopter deficiencies as "the single most critical shortfall in the Fleet Marine Force inventory." This was a very powerful statement considering we were in the height of the Vietnam Conflict.⁸ The result was the continuation of the Heavy Lift Helicopter program.

One could easily argue that in Vietnam, the penalty for not having the heavy lift capability was in the neighborhood of \$510 million. It cost that much to build a port facility capable of handling the U.S. throughput.⁹ The port of Danang was built up to handle the logistical throughput of sustained United States operations. Materials were off loaded at Danang and then reshipped in smaller craft capable of traveling to the shallow coastal regions. Or were loaded onto trucks and delivered by road, resulting in multiple handling, delays, and high in-transit risks. These problems could have been eliminated had the U.S. had the ability to lift the material from the ship and deliver it directly to the unit.

The inability to conduct the heavy lift missions in Vietnam was paramount in determining the requirements of the modern day CH-53E. The advantages the CH-53E brings to the fight hold true today given the inability of most countries to handle the logistics throughput of a large coalition force. Because we cannot determine the time, location, and size of the next contingency operation, we cannot predict where these facilities should be built. The tempo of these operations may not provide the time to build the required facilities. History continues to prove that we are going to go to war with what we have. Today the CH-

⁸ Brief to the Armed Services Committee, N.P., N.D., received from PMA-261, Colonel Croisietiere, 29.

53E provides tremendous options for getting gear, personnel, and equipment ashore and in the fight.

Throughout the late 1960's and early 1970's there were considerable joint efforts to define the HLH requirements. There were significant differences in the required capabilities that ultimately led to separate programs being developed for the Army and the Navy. At one point, the Navy requirement of a vertical lifting capability of 18 tons was the short-term goal; the Army requirement of 20 to 30 tons was the long-term project goal. These significant differences could be attributed to the Army's unwillingness to sacrifice lift capability for shipboard compatibility.

In May 1971 Under-Secretary Packard announced that the Army's HLH was not acceptable for the Navy/Marine Corps and authorized the Navy to develop a smaller shipboard based helicopter that would result from upgrading an existing inventory aircraft (CH-53). Thus, the CH-53E program was born amid favorable endorsements from all congressional committees acting in the FY-73 authorizations and appropriations processes.

The Army and Navy programs ultimately went in different directions. The naval services developed the CH-53E and the Army stayed with the venerable CH-47 Chinook. Given the operational successes of Marine heavy lift in missions that were of great importance to national prestige, it would be interesting to see what the Army would do in the way of establishing heavy lift requirements if it could turn the clock back 30 years!

The program started with an initial fabrication and test of two prototype helicopters that were completed by May of 1974. The aircraft displayed greater performance than anticipated. The most significant performance parameter exceeded was the aircraft hover

⁹ Congressional Testimony, N.P., N.D., received from PMA-261, Colonel Croisetiere, 12.

weight.¹⁰ The requirement was 69,750 pounds at sea level, 90 degrees Fahrenheit, and a 20-foot wheel height. The aircraft demonstrated a hover capability of 75,000 pounds, exceeding the requirement by seven percent.¹¹

The initial acquisition plan called for the purchase of 70 aircraft. This would allow the Navy and Marine Corps to each receive 35. The Marine Corps plan was to provide one squadron of 15 aircraft on each coast. The Department of Defense requested additional funds for fixed wing Carrier On-board Delivery (COD) aircraft resulting in a decrease of total aircraft purchased from 70 to 49. The net result was a decrease in the total program cost but an increase in aircraft unit cost from \$5.34 to \$6.11 million (in 1973 dollars).

In the 1980's as the program matured through the testing and evaluation phase, its numbers were increased from 49 to 126. The numbers were again increased in 1982 to approximately 160 aircraft. Subsequent budgetary plus ups have provided additional CH-53's up to 1999 when the Marine Corps received its last CH-53E.

The United States Marine Corps deploys as a complete operational force that once tasked is capable of completing a variety of strategic missions. The Marine Corps differs from the other services because it can operate as a quick reaction all arms force. Through its close relationship with the Navy, the Marines can project the capabilities of the Marine Air Ground Task Force (MAGTF) around the globe. This was readily apparent during the Gulf War. According to the Government Accounting Office, the Naval Services were able to sustain themselves better than the other branches of the services.¹²

¹⁰ Aircraft hover weight is defined as the aircraft basic weight (to include fuel and crew), payload (internal and/or external loads).

¹¹ CH-53 Program History, N.P. N.D., received from PMA-261, Colonel Paul Croisetiere, 20.

¹² GAO REPORT, The Services' Efforts to Provide Logistics Support for Selected Weapon Systems, September report 1991 GAO/NSIAD-91-321, 4

One of the reasons for the success of the Navy-Marine Corps team is that they are always forward deployed aboard ships and routinely train in the movement from ship-to-shore in some of the most unforgiving environments. While other services consider being forward deployed as falling in on a built-up area with functioning infrastructure, the United States Marine Corps routinely operates around the globe in austere environments. Like the Carrier Battle Group, the Amphibious Ready Group, with large deck amphibious ships represents that critical piece of sovereign United States territory that has the flexibility to reposition itself according to the situation, while remaining independent of host nation support.

The key to the CH-53E's strategic and operational relevance is multifaceted. First, the aircraft's ability to carry out a wide variety of missions is critical to both our national interests and prestige. There are three operations that aptly demonstrate the strategic and operational relevance of the capabilities of the CH-53E:

- Operation EASTERN EXIT
- The recovery of Basher 52 (Captain Scott O'Grady Rescue)
- Operation ENDURING FREEDOM (covered in the next chapter)

Operation EASTERN EXIT

The mission was in response to the request to evacuate U.S. personnel and others from the U.S. Embassy in Mogadishu, Somalia in January 1991. Forces from the 4th MEB were operating in the Arabian Sea when called upon to proceed to the coast of Somalia for the Non-combatant Evacuation Operation (NEO). The flight of two CH-53E's carrying the 60-man force (Navy Seals and Marines) made the 466-nautical mile flight from the ship to the embassy. After an hour on the deck, the CH-53E's took to the air to return back 380-nautical miles to the ship with a total of 61 evacuees.¹³

¹³ Adam B. Seigel, *Eastern Exit: The NEO from Mogadishu, Somalia, in January 1991* CNA, 3

Analysis of this operation showed that the CH-53E provided the operational commander with a uniquely significant capability to influence this situation. The capabilities of the CH-53E not only ensured the required forces and equipment could be inserted; but more importantly the aircraft provided the flexibility to provide safe passage for the American Ambassador and American citizens of the embassy staff. In both cases over 30 passengers were carried on both ingress and egress on each aircraft. The CH-53E not only went the distances that were required, but also carried a significant payload.

Recovery of Basher 52

Captain Scott O'Grady's F-16 was shot down while flying over Bosnia on the 2nd of June 1995. The 24th MEU(SOC) was off the coast providing Tactical Recovery of Aircraft and Personnel (TRAP) support, augmenting the theater Combat Search And Rescue (CSAR) assets. When the call to recover Basher 52 came in, the CH-53E was the aircraft of choice. The CH-53E could not only aerial refuel and remain on station ,but also carry a sufficient Ground Combat Element (GCE) in the event the recovery operation was contested.

This operation represented the exploitation of an aircraft capability. The aircraft originally procured to recover aircraft was performing the more demanding tactical mission of retrieving the pilot in hostile territory. Moreover, this particular mission contributed significantly to the national perception that the Marine Corps is the force of choice for the most demanding missions, further reinforcing the relevance of both the CH-53E and the Marine Corps in their relative contributions to the National Military Strategy. There are some who would say the aircraft was not designed to execute that type of mission, but what aircraft is performing the mission it was originally procured to accomplish? The high level of training, competence and flawless execution helped to ensure mission success. The CH-

53E was not only the logical choice for the mission; it would be easy to make the argument that it was the only choice.

CHAPTER 2

CURRENT HEAVY LIFT REQUIREMENTS

When the CH-53E was originally procured it could transport 96 percent of the FMF's gear.¹⁴ This includes the gear that is currently embarked on the MPS ships, slated to go with the MEF, MEB, and the MEU. Since Vietnam the CH-53 has seldom performed the heavy lift mission for which it was designed. Instead the CH-53E has become the platform of choice for a wide variety of missions, including many which are medium lift missions.

In an article in the DEFENSE DAILY the Department of Defense acquisition chief Mr. E.C. "Pete" Aldridge was quoted as saying:

In the "unlikely event" that the V-22 fails, such alternatives include the Sikorsky S-92 helicopter, the Agusta Westland EH-101 helicopter and upgrades of existing helicopters, such as the CH-53.¹⁵

This statement could create the perception on Capitol Hill and in the Marine Corps that there are two aircraft that could compete as a medium lift replacement. Additionally, one platform could replace both with a resulting savings in crew, parts, training, and aircraft. This statement fosters the perception that the SLEP of the CH-53E is only required as an alternative if the MV-22 program fails. What these perceptions fail to identify is that there are two separate requirements that cannot be met with just one platform. Heavy lift is its own requirement. The CH-53E SLEP is not a MV-22 alternative but rather a synergistic addition to Marine assault support. Regardless of the outcome of the MV-22, the CH-53E requires the SLEP. Current Marine Corps concepts, doctrine, and posture statements speak glibly of Expeditionary Maneuver Warfare (EMW), STOM, and OMFTS. All these envision putting substantial and very capable Marine forces well inland. More "transformational" aircraft offer seemingly superior capabilities.

¹⁴ Congressional Testimony, N.P. N.D., received from PMA-261, Colonel Paul Croisetiere, 15

¹⁵ Gildea, Kerry, Defense Daily, *Pace Calls For More Proactive JROC Process*, April 10, 2002.

Due to its “Over the Horizon” capability, an essential part of the relevance of today’s MEU is the CH-53E. The CH-53E can travel great distances and go where there are no airfields; its crews are trained for a variety of missions, and as part of a MEU is forward deployed in nearly all regions of the world. This helps to keep the MEU part of every CINC’s theater engagement plan. The second question the CINC asks after wondering about the whereabouts of his MEU is “...how many ‘53s are up?”¹⁶ When the CINC’s ask where is the MEU, they are in essence asking, “where are my CH-53E’s?”

The CINC’s can use nearly any fixed wing assets in theater to provide Close Air Support (CAS), but the ability to go great distances with a significant payload of Marines and their equipment and to land without an airfield provides commanders ultimate flexibility.¹⁷ Lieutenant General Nyland the Marine Corps Deputy Commandant for Aviation said,

It all comes back to the MAGTF (Marine Air Ground Task Force), air power is a vital piece here, but it doesn’t hold ground. If you want to have a desired and lasting impact, then you have to put troops on the ground. That means putting Marines or soldiers ashore and holding key terrain to enable things to happen.¹⁸

More than any other service, the United States Marine Corps has been in the right place, at the right time, and with the right forces due to the capabilities of the CH-53E helicopter.

CURRENT FORCE STRUCTURE

Based on the current force structure the Marine Corps is using the aircraft as effectively as possible. There are several alternatives to make the use of the CH-53E more efficient and in doing so increase its effectiveness.¹⁹ It is necessary to understand the current

¹⁶ Helland Samuel T., Brigadier General, USMC. CO 22 MEU(SOC) Operation SILVER WAKE. Keynote Address given during the annual H-53 Fleet Support Team (FST) Meeting, Virginia Beach, VA March 2001.

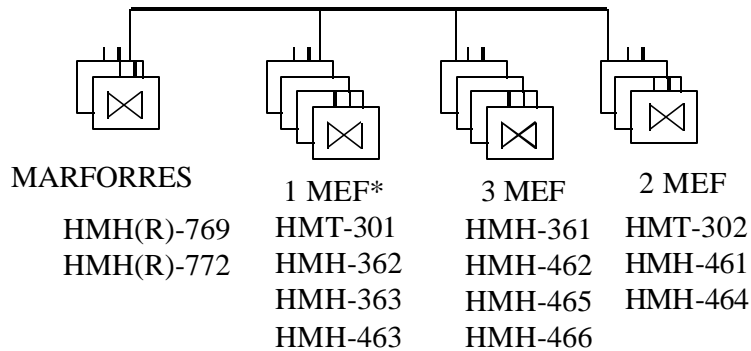
¹⁷ This has been validated with B-52’s in Operation ENDURING FREEDOM dropping GPS guided munitions. Flexibility for the purpose of this paper means providing the commander multiple options when looking to accomplish an assigned task or mission.

¹⁸ Guardiano John R., “Battlefield Intelligence”, *Rotor and Wing*, online edition, January 2002. URL:<<http://www.aviationtoday.com/reports/rotowing/previous/0102/0102military.htm>>, accessed 22 March 2002. Cited hereafter as Guardiano, “Battlefield Intelligence”.

¹⁹ These alternatives will be discussed in the next chapter Future Heavy Lift Requirements.

CH-53E force structure before considering future weapons system and manpower requirements.

Current Task Organization



* 1 MEF HAS CH-53D's & 1 CH-53E 3 MEF SQUADRON UDP

Squadrons

There are currently six active duty and two reserve CH-53E squadrons. Four active duty and one-reserve squadrons are located on the West Coast. Two active duty, one reserve, and one training squadrons are on the East Coast. There are four CH-53D squadrons located in Hawaii, which include three active duty and one training squadrons. Currently the CH-53D squadrons and the two reserve CH-53E squadrons are slated to convert to the MV-22.

Manning

Currently there are enough forces to meet the operational commitments of the Marine Corps in a peacetime environment. The Marine Corps isn't about being most ready for peacetime, the Marine Corps is about being most ready for war when the Nation is least ready.

The call, "Send in the Marines!" Has been sounded more than 200 times since the end of World War II, an average of once every 90 days. Our nations leaders have great confidence in the Marine Corps ability to succeed anytime, anywhere and in any situation. The basis for such confidence is a highly effective form of operations uniquely suited to the Marine Corps' statutory role as the nation's force in readiness.²⁰

As the Marine Corps takes its part in the global War on Terrorism, it is readily apparent that our CH-53E squadrons are being stretched thin. In a move to alleviate the operational tempo on our active duty CH-53E squadrons, both reserve squadrons on the East and West Coast have been called upon to assist the active forces. On both coasts, MEU Commanders have asked for double the number of CH-53E's (from four to eight) per MEU (ACE) detachment to meet the requirements of the missions they anticipate being called upon to complete.

One of the reasons this is a significant challenge is that the CH-53E community is manned at 75 percent of its Table of Organization (T/O) rates or at staffing goals.²¹ By contrast the MEU detachments are manned at 100 percent of T/O. When squadrons send out two detachments, as is the case on both East and West Coasts in support of the MEU's, the base CH-53E squadron is left with approximately 25 percent of the required people to man

²⁰ *Send in the Marines: The Art of MAGTF Operations*, Marines Almanac, January 1998

²¹ Staffing Goals are the rates at which it is thought that a unit can effectively operate during peacetime. In the event the unit were to be activated for combat it would require additional manning or plus up to the Table of Organization rate. There are several problems with this practice, in the event the unit is activated where do the trained individuals come from? In the aviation community the newest pilot, crew chief, and mechanic show up to the operational squadron with a significant amount of initial training that represents a considerable investment in time and money that cannot be easily condensed to facilitate a crisis.

50 percent of the assets. This cyclical reduction in manning has a significant deleterious effect on a squadron's ability to provide effective support. These are the perils of regular training and deployment cycles without the additional requirement of doubling up detachments. If the CH-53E community continues to operate at these levels, a training, retention, and readiness "train wreck" is inevitable.

This inability to train the base squadron directly affects the ability to maintain adequately qualified personnel for future detachments and deployments. Base squadrons are very limited in the ability to conduct training, let alone provide support for the Marine forces.²² This is an example of a community that has been doing more with less to the point of being marginally effective when two detachments are deployed in support of MEUs. The force structure of the CH-53E squadrons must be reassessed.

We must first look at our capabilities to meet the requirements of both peacetime and Major Theatre War requirements with our current force today before we can assess where we need to go tomorrow. We will look at the CH-46E and the CH-53E as the assets that will move the MAGTF of today.

If we are truly a task-organized force concerned with effects based operations, then we should develop a force structure that is based on the missions we expect to be called upon to accomplish. The MV-22 brings much that is new to the medium lift aircraft; it will provide greater range, speed, and survivability. The CH-53E has a significantly greater lift capability than the MV-22. If the future of Marine Aviation is truly in the direction of the tilt-rotor then it is necessary to master the concepts in the medium lift arena before venturing into a heavy lift tilt-rotor.²³

²² CH-53E squadron T/O's are set-up to provide two, four aircraft detachments and have the ability with the remainder of the squadron, referred to as the base squadron, to train and conduct normal operations.

²³ Hanks, Thomas. Colonel, USMC, MIT Fellowship, *Future Marine Corps Heavy Lift Rotorcraft: A Brief Report on Current Alternatives for 2025*. May 2000.

Marine Aviation Requirements Study (MARS)²⁴

In August 2001 the Assistant Deputy Commandant of the Marine Corps for Aviation and the Deputy Commanding General for Combat Development of the Marine Corps Combat Development Command (MCCDC) sponsored a study conducted by the Center for Naval Analysis to determine the correct force structure for the future of Marine Aviation. The MARS was conducted as a four-part analysis to determine the correct force structure based on possible employment scenarios from peacetime to major theater war.

The study successfully captures the deployment and operational commitments of Marine Aviation. It makes great strides in attempting to quantify the required numbers of aircraft to match the required capabilities through all potential employment spectrums. It goes into significant detail regarding the utilization, availability, and attrition of aircraft. Capturing this information represents one of the more difficult aspects of determining the future force structure. In doing the study certain assumptions were made that directly affect the outcome of the results.²⁵

So the only point I am trying to make is that the conclusions one draws in this debate are going to be driven by the assumptions one makes. If you make a different set of assumptions, you are going to get a somewhat different set of results.²⁶

This quote is as relevant today as in 1990 when Dr Chu was testifying before the Senate Appropriations Committee regarding the operational effectiveness, cost effectiveness, and affordability of the V-22 program.

²⁴ Dr. Gary Phillips, Major Eric Damm USMC, Dr Tom Bowditch, Mr. Anton Jareb, Mr. Robert Bendow *Marine Aviation Requirements Study: Summary Report*, August 2001(Center for Naval Analysis Research Memorandum D0003922.A2).

²⁵ The studies were performed by the Center for Naval Analysis, the intent was to identify complete Marine Corps aviation requirements across the spectrum of operations from peacetime through major theater war (MTW). It appeared to take requirements and justify the number of aircraft required. In this authors opinion it took requirements and molded them to meet already projected aircraft procurements.

²⁶ Dr. David Chu, Head OSD PA&E, Senate Testimony 1990

When trying to determine the capability requirements for today and tomorrow one must also make certain assumptions. The way in which the data is depicted will make a significant difference in the outcome of analysis. The MARS reports made several assumptions that are questionable:

- The current force structure is correct for the future.
- The baseline metric was the MV-22 fleet, meaning alternative aircraft were critiqued against the MV-22, not the Marine Corps optimal needs.
- Artificial limitations imposed on comparison aircraft
- Performance parameters were incorrect for the CH-53E

First, the study assumed the current force structure ratio of three medium lift to one heavy lift asset was best. This is important because as we look to determine which aircraft will meet the requirements, the correct quantity of those aircraft are equally important to ensure we are able to accomplish the mission. To assume that the current ratio of aircraft is correct without exploring the possibilities is a missed opportunity to maximize the potential benefits of the future force. Perhaps a deviation from the currently accepted force structure would be beneficial. The MARS appeared to validate decisions that had already been made, instead of truly looking to determine what Marine Aviation requirements would be in the future.

Secondly, the reports used the MV-22 force as the baseline. It would make sense to use the current force (CH-46 and CH-53) as the baseline given the fact that its capabilities and limitations are widely known. Using aircraft capabilities in an aircraft that has yet to reach a full rate production decision is a high-risk assumption.

Thirdly, the study limited the passenger capacity of aircraft with a greater than 24-passenger capacity to a limit of 24 (which coincidentally is the MV-22 limit). While 24-passengers is accepted as a peacetime planning/training standard, it would be unwise, even foolish, when considering Major Theater War and combat operations to not use an aircraft's

true capability for building combat power. Operationally, the number of passengers is left to the discretion of the MAGTF commander. A typically accepted practice is ensuring all passengers have seat belts and crash-attenuating seats has been a typical limitation applied in most non-extremist situations.

Finally, the performance data for the CH-53E based on the given ambients was incorrect. The CH-53E has the ability to lift 13,500 pounds vice the 12,000 pounds listed in the study. Because the CH-53E was the one aircraft whose requirement was constant, it might appear that the small differences might be easily dismissed. When looking at the number of sorties, and comparing the capability of the combinations of the aircraft to meet a specific threshold, however, that 1500 pounds equates to 0.75 short tons or a total of five passengers per sortie. This fact could potentially change the outcomes when the results are close.

It was determined in the study that the following medium and heavy lift force structure could support the assault support peacetime requirements.

Total Squadron Requirements

Type	Deployments	Exercises	3:1 Rotation	4:1 Rotation
HMM	3 - 4	2 - 3	11 - 15	14 - 19
HMH	1 1/2 - 1 3/4	1/2 - 1	5 - 6	7 - 8

This represents the total number of squadrons required to support normal peacetime deployments and exercises that involve more than one squadron (other than squadron only training). The 3:1 rotation is based on being deployed six of 18 months allowing 12 months between deployments. A 4:1 rotation would have the units deployed six months out of 24, allowing 18 months between deployments.

A way to realize the full potential of the MV-22 is to look at having the same number of MV-22, CH-53E, and HMLA squadrons and aircraft. This will allow the ability to make the ACE a separate command from the medium lift squadron. In essence this would allow it

to be truly task-organized unit. For the typical forward presence deployment the ACE might be comprised of six MV-22's, six CH-53E's, six AH-1Z's, and three UH-1Y's. The ACE could be commanded by any qualified Lieutenant Colonel, not necessarily a medium lift squadron commander.

The squadrons could be set up to have the ability to have two detachments gone at a time but only one would be committed to a MEU deployment; the other would be ready in the event of a contingency. The third detachment could be the training detachment, focused on getting the next generation of aircrewmen, mechanics, and technicians qualified and wouldn't be deployed unless there was a MTW.

Designating a particular squadron to support a MEU would help to stabilize the deployment cycle for units and personnel. A detachment might represent one-third of a squadron. The first time the MEU deploys the first detachment would deploy. Upon return the second detachment would be ready to assume the role of the deploying detachment. The senior pilots could roll into the third detachment and be the instructor base for the squadron. This would allow for a more stable progression for aircrew. This will have a positive effect on retention for highly deployed units. This would allow for a detachment for any CONUS exercises, unplanned contingencies and not jeopardize the training base of young pilots, aircrew, and mechanics.

The following represents the capability of these deployments based on the current Aviation Combat Element (ACE) structure in lift and range. The capabilities of the entire HMM squadron were calculated as well for future reference.

Headquarters Marine Corps (Aviation) provided data used in the calculations for CH-46E payload and ranges. The CH-53E NATOPS performance charts were used to determine the capabilities of the CH-53E.

Current Capabilities

The following table represents what the true capabilities of the current CH-53E. The numbers reflected in the CNA study were not accurate of the aircraft capabilities based on the given ambients. The number was derived from the Performance Charts in the CH-53E NATOPS.

MARS data modified to represent true CH-53E capabilities.

AIRCRAFT	TROOPS LIFTED	SPEED (KNOTS)		NOMIMAL LOAD	REFUEL MINS	MISSION RATES
		INTERNAL SPEED	EXTERNAL SPEED ^a			
CH-46	14	110	100	3800	10	80
MV-22	24	240	110	9000 ^b	15	80
CH-53E	32 ^c	135	110	13500 ^d	20	70
CH-53X	32 ^c	135 (150?)	110	32500	20	75
<p>a. Air Air speed is dictated by FM 55-450-4 and FM 55-450-5. External load speeds are an average of lifts carried by the aircraft.</p> <p>b. Troop lift capacities are based on aircraft capabilities and representative of how the aircraft has been employed in recent combat missions.</p> <p>c. The numbers for the MV-22 were taken from the CNA Study.²⁷</p> <p>d. The numbers reflected in the CNA study were not accurate of the aircraft capabilities based on the given ambients. The number was derived from the Performance Charts in the CH-53E NATOPS.</p>						

²⁷ Dr. Gary Phillips, Mr. Robert Benbow, and Mr. Anthony M. Jareb. Marine Aviation Requirements Study (MARS): Follow-on Assault Support Analysis: MV-22 Quick Look. CRM D0005127.A2/Final, December 2001,

Total Force Capabilities

Total aircraft	Availability	Capability	SingleWave Lift	Range
HMM 12	80%= 9 A/C	3800lbs/14 Pax	34200lbs/126 Pax	127NM
HMH 4	70%=2 A/C	11750lbs ^a /43 ^b Pax	23500lbs/86 Pax	127NM ^c
HMH 4	70%=2 A/C	13500lbs ^d /49 Pax	27000lbs/98Pax	85NM
HMH 6	70%=4 A/C	11750lbs ^a /43 ^b Pax	47000lbs/172 Pax	127NM ^c
HMH 6 ^d	70%=4 A/C	13500lbs ^d /49 Pax	81000lbs/294 Pax	85NM
HMH 16	70%=11 A/C	11750lbs ^a /43 ^b Pax	129250lbs/473 Pax	127NM ^c
HMH 16 ^d	70%=11A/C	13500lbs/49 Pax	148500lbs/593 Pax	85NM
^a Based on CH-53E NATOPS, 3000' PA, 91.5 degrees F, 5 percent power margin in the HOGE 103 percentNr, 36500 BW, 1000 lbs crew wt, 1500 lbs fuel NATOPS minimum. ^b Based on centerline seats and each Marine weighs 271 lbs ^c Extendable with aerial refueling ^d Based on ambient conditions in the CNA MARS of 3000' Pa, 91.5F, with 5 percent power margin in HOGE. Total distance to take loads of 85 NM, total lift capability is 13500 pounds, or if divided by the 271 lbs per Marine (used in MARS) represents the total number of Marines that could be lifted with centerline seats installed. For the purpose of the paper 32 Marines will be used to keep in line with normal standard configuration of seat belts and crash attenuating seats.				

The CH-53E currently has the capability to provide 3.55 CH-46E sorties per every CH-53E sortie when considering cargo (CH-46E carrying 3,800 pounds). The CH-53E has the ability to provide 2.2 sorties when carrying passengers (CH-46E carrying 14 passengers). The CH-53E has greater passenger carrying capability with centerline seats installed but this is unrepresentative of how the aircraft has been employed in Operation ENDURING FREEDOM.

The MEU currently has the ability to project power out to 127 nautical miles with its assault support assets.²⁸ From the time the first wave of CH-46E's lifts off it will take 1+10+00 (H/M/S) to get to the objective area. The CH-53E's will be able to accomplish the

same leg in 1+00+00 at maximum range airspeed of approximately 127 knots indicated airspeed. Assume five minutes in the zone for drop off and the same time to get back to the ship. Total time for the first wave of 46's and 53's will be 2+25+00. This wave could be 212 total passengers or a total of 57,700 pounds (28.85 short tons) of cargo. This is a simplified version, but it illustrates what the capabilities are of the current forces. There are inherent limitations with the force such as deck spotting, refueling, loading of Marines, but they will be applicable regardless of the aircraft used to move the forces.

Therefore, if we were to apply these factors to today's MEU movement from ship to shore of two reinforced rifle companies comprised of 424 Marines, six HMMWV's (2-MRC-145, 2-TOW, and 2 Armored) and 45.8 short tons of supplies it would look like this:

Current MEU Force Capability 3:1

		Pax		Vehicles	STONs	Ext Lifts		Sorties	
	TIME	46	53			46	53	46	53
Wave 1	2+45	126	28	2	0	0	2	9	2
Wave 2	2+45	126	28	2	0	0	2	9	2
Wave 3	2+45	116	0	2	3.25	0	2	9	2
Wave 4	2+45	0	0	0	28.85	0	0	9	2
Wave 5	2+05	0	0	0	13.70	0	0	2	2
Totals	13+05	368	56	6	45.8	0	6	38	10

This table reflects the capabilities of the current medium and heavy lift helicopters. The ratio of medium lift to heavy lift is 3:1 based on the HMM PAA of 12 aircraft and the HMM detachment of four CH-53Es. The Aviation Combat Element has routinely been built around the HMM squadron.

If we were to look at another option of changing the medium lift to heavy lift ratio to 2:1 by increasing the number of CH-53E's (to six) we would remove the 5th wave and see a

²⁸ The ability to project power in this study is the ability to take a payload the required distance, drop-off the payload, and return without requiring fuel before reaching the starting point.

22 percent decrease in time to accomplish the mission with today's current force augmented by two additional CH-53E's.

Force Structure 2:1 Ratio

		Pax		Vehicles	STONs	Lifts		Sorties	
	TIME	46	53			46	53	46	53
Wave 1	2+45	126	22	4	0	0	4	9	4
Wave 2	2+45	126	76	2	0	0	2	9	4
Wave 3	2+45	74	0	0	29.5	0	0	9	4
Wave 4	2+05	0	0	0	16.3	0	0	0	3
Totals	10+20	326	98	6	45.8	0	6	27	15

The entire mission could be accomplished in 10+20 (HH+MM) a total savings of 21 percent or two hours and forty five minutes, and elimination of the fifth wave with the additional two CH-53E's. The ability to just add additional CH-53E's does not come without consequences with today's marginal force structure.²⁹

Operation ENDURING FREEDOM

Operation ENDURING FREEDOM represents the first phase of the Global War on Terrorism that followed the murderous events of September 11, 2001. Marines embarked with the 13th MEU(SOC) were the first to receive the call to action. The first mission the Marines were called upon was to recover a downed MH-60 Pave Hawk. The CH-53E was the platform of choice due to its ability to lift the entire aircraft with minimal maintenance preparations. This mission represented savings to the United States government of one

²⁹ This much like the "Single Battle Concept" where the CH-53E community represents that indivisible entity a single action (plus-up, contingency operation, unexpectedly high utilization rate) in one part of the community may have a profound and often unintended effects on other areas or events. The current force structure doesn't allow for the continuous support of detachments with additional aircraft. In the next chapter a detailed analysis will offer an alternative to make this possible.

special operations equipped MH-60, a very expensive aircraft! The recovery of this aircraft also potentially represented a boost in national prestige.

The next mission the Marines were called upon to accomplish required assets from both the 15th and 26th MEU(SOC)'s. Operating as two separate ACE's, the two MEU's conducted the longest overland insertion of Marines in the history of the Corps. It also represented the largest increase in operational tempo for the CH-53E community, as at one point there were 24 CH-53E helicopters supporting operations in Afghanistan. This is approximately one-sixth of the entire CH-53E fleet.

Again, the helicopter of choice was the CH-53E. The legs were approximately 350-400 nautical miles inland across Pakistan into Afghanistan. For the insertion to Camp Rhino the seven CH-53E's were loaded with approximately 30 (not 24!!) personnel each weighting approximately 350 pounds for a total weight of 10500 pounds. These weights are significantly higher than normally planning figures due to the distance, environmental conditions, and unknown time on the ground. The aircraft were to aerial refuel once en route to ensure they had the fuel to complete the mission and return to a base back in Pakistan. There was some difficulty with the aerial refueling evolution; however, all aircraft made it to the insertion zone. The aircraft that were not able to refuel from the tanker waited until the C-130 landed and was able to conduct a Rapid Ground Refueling (RGR). All aircraft recovered at their intended destination.

The capability to carry a significant payload and fuel allowed the CH-53E to accomplish this mission in spite of the difficulties encountered with the aerial refueling evolution. A plan with less capable aircraft would not only require more aircraft to move the Marines and equipment but also increase the requirement for aerial refueling assets.

The challenges encountered in the following weeks at Camp Rhino stemmed more from environmental challenges than from the enemy. The Marines maintained a high state of alert for any possible missions that might come up. One such mission did come; an errant bomb hit American Special Forces. The CH-53E was again called into action to perform a mass casualty evacuation mission. The single CH-53E took 40 wounded personnel from a mountain location. The aircraft was able to successfully lift all the personnel in one lift. Other aircraft most likely would have required two sorties due to the space limitations in the cabin and the weight of the personnel and gear they carried.

Navy Heavy Lift

In the recent past the Navy has considered moving to an all H-60 helicopter force. It was apparently determined that by eliminating the MH-53E, and going with a less capable helicopter, that the Navy could lower life cycle costs while retaining the same capability. What they failed to realize is that streamlined supply and initial savings in cheaper cost per flight hour don't always equal the required capability. Sometimes you need something that can carry a lot of stuff and then go a long way. This is where the MH-53E has earned its keep with deployed naval forces.

The missions the MH-53E's are accomplishing in support of Operation ENDURING FREEDOM are impressive. According to the Heavy Lift Quarterly, the Black Stallions of HC-4 externally lifted a downed Air Force MH-53J Pave Low. The 19,000-pound aircraft was transported 30 miles from the NATO Pier in Augusta, Sicily to NAS Sigonella.³⁰ Without this capability, the DoD would have had a complex challenge in moving a badly damaged helicopter from an isolated pier to an air facility capable of supporting a C-5/C-17 lift of this helicopter.

³⁰ PMA-261, "Need A Lift", *The Heavy Lift Quarterly*, March 2002, 12. URL:<<http://pma261.navair.navy.mil>>

The Navy MH-53's were also providing heavy combat support to the forces operating in support of Operation ENDURING FREEDOM. In January they flew 20 days for 104 hours, but delivered 214,000 pounds of cargo and 68,000 pounds of mail to three carriers and other support ships, along with 132 passengers, 11 aircraft engines, and accomplished one MEDEVAC.³¹

Support For Special Missions

The Commandant of the Marine Corps recently signed an official Memorandum Of Agreement (MOA) between the Marine Corps and Special Operations Command (SOCOM). As has been seen in Operation ENDURING FREEDOM, this serves to strengthen the relationship between these two forces. The Marine Corps is not looking to replace units in special operations but rather provide complementary forces that are currently deployed world wide and trained to accomplish the mission.

One such way the relationship could be complementary is through the use of Marine aviation forces. Currently these forces deployed world wide, trained, and ready to provide the additional long range over the horizon support they might require. The aircraft of choice will be the CH-53E for the foreseeable future. Even with the introduction of the MV-22, the aerial refueling capability of the CH-53E complements existing special operations platforms, the MH-53J, MH-47, and the MH-60K. The CH-53E has the potential to provide Special Operations Forces (SOF) the additional lift and range for their required payloads.

³¹ PMA-261,"Need A Lift", March 2002, 12.

CHAPTER 3

FUTURE HEAVY LIFT REQUIREMENTS

The United States Marine Corps as well as all services are currently in the process of justifying their existence through a continued review and validation of the roles and missions they are responsible for being able to perform. The Marine Corps is no different from the other services, trying to provide the most capability for the least amount of money, competition for the limited fiscal resources of the defense budget. All services are clinging to the buzzwords of “Transformational” and “Expeditionary”.

If the Marine Corps is truly looking to “transform” then it should look at all aspects of the transformation. Force Structure is one such place that we should look to achieve change. The Marine Corps has long tied its ability to accomplish EMW with the MV-22 and the AAV programs. The new technology-centric systems the Marine Corps has envisioned using to make these concepts reality will, if successful, enhance our capabilities but at a cost of an increased sustainment requirement.

We are replacing the CH-46 and the AAV with vehicles that have the same or less cabin space respectively. These Marines will be in tight quarters with little room for themselves let alone their gear and equipment. The tradeoff in both cases will be fewer Marines or less gear and equipment. To facilitate this increase in maneuverability, the forces are going to be put on the battlefield with less gear than in the past. Evidence from the Operation ENDURING FREEDOM suggests Marines and soldiers are carrying larger than normal quantities of gear and equipment for the austere environment they are being called upon to operate.

There is a common misconception that the forces of the future are getting lighter, while this may be true for the individual Marine; it isn't so for their equipment. Looking at the next generation of planned equipment, we see that it is just the opposite; the force is getting heavier. Even with the advent of greater technology, the force is still getting heavier, not lighter. The old 9000 series 5T-Truck weighed 21,740 pounds; the replacement MTVR 7T-Truck weighs 27,500 pounds. The CH-46E weighs 15,537 pounds, and its replacement the MV-22 weighs 33,150 pounds. The AV-8B weighs 14,867 pounds, and the Joint Strike Fighter is forecasted to weigh 22,500 pounds. Perhaps the generation after next will see the technological breakthroughs that will make this a reality.

The questions one must ask are:

- a. Whether the CH-53E is irrelevant with the promised introduction of the MV-22 and the AAV, and
- b. Whether the proposed force structure would be able to accomplish the missions with the current and projected number of CH-53E's?

The answer to both questions is no. The MV-22 is a viable external platform but only with a payload below 10,000 pounds. While conducting externals it doesn't have the ability to aerial refuel and experiences a significant decrease in its speed. The present force structure of 3:1 medium lift to heavy lift aircraft requires further study as well.

If the V-22 cannot rapidly move operational equipment, then its utility as an external cargo carrier to replace current Marine Corps medium-lift assets will have to be reevaluated.³²

According to the MARS completed by the Center for Naval Analysis (CNA), the MV-22 will be required to carry externals for forty-eight percent of its sorties in the

³² U.S. General Accounting Office, *Navy Aviation: V-22 Cost and Capability to meet Requirements Are Yet to Be Determined*, GAO/NSIAD-98-13 (Washington D.C.:Oct, 1997), p 5.

movement of a Regimental Landing Team (RLT).³³ This requirement severely degrades the speed advantage of the MV-22. When carrying externals, e.g. fuel, munitions, and vehicles, the MV-22 cannot fly anywhere close to its top airspeed. This airspeed limitation is not a function of the aircraft but rather the external load aerodynamics and drag.

AIR-RLT Regiment sized movement³⁴

Assault Echelon	Pax	Vehicles	Lifts			MV-22 Sorties	CH-53E Sorties
			MV-22 Int	MV-22 Ext	CH-53E Ext		
Wave 1	1798	50	62	14	36	76	36
Wave 2	976	73	37	38	35	75	35
Wave 3	271	102	4	71	31	75	35
Wave 4	0	6	38	0	18	38	18
Total	3045	225	141	123	124	264	124

Per the study, the MV-22 is required to perform 123 external sorties of its total 264 sorties. As previously mentioned this does not maximize the speed advantage or enhance the survivability of the aircraft. One solution might be to go back through our existing inventory and redesign all our equipment to ensure it is capable of being externally carried under the MV-22 at a speed closer to its best airspeed.

Alternatively, we could ensure there are enough CH-53E's to maximize the MV-22's potential. The only way to truly realize the full potential of the MV-22 is to ensure we have the synergistic relationship between the medium and heavy lift aircraft working together to accomplish the mission. But the CH-53E is an aging aircraft. It reached the fleet in 1980, and there have been minimal improvements to the aircraft and few budget initiatives to ensure it is as capable today as the day it came from the factory.

³³ CNA, MARS *Follow-on Assault Support Analysis: MV-22 Quicklook*, Dec 2001 pg 21

³⁴ Center for Naval Analysis, MARS *Follow-on Assault Support Analysis: MV-22 Quicklook*, Dec 2001 p 21.

There is a dilemma with the current projected force structure and its ability to meet future requirements. There are not enough heavy lift assets to accomplish OMFTS and STOM out to the 200 nautical miles originally conceived. The projected force structure is not capable of supporting these concepts without 100 percent utilization of all of the CH-53E assets in the inventory.

MV-22 and CH-53E unit movement requirements for total aircraft.³⁵

Aircraft	Element	Peak Sorties Flown	Sortie rate		Total Sorties ^a	Aircraft required:			Total Aircraft
			Peak	Avg ^b		to fly sorties	for avail-ability	for attrition	
MV-22	AIR-RLT movement ^c	264	3.5	1.8	2028	76	20	8	104
	AIR-TF movement ^c	264	3.5	1.8	2056	76	20	8	104
	AIR-RES	71	2.0	.9	497	36	9	2	47
	Non-unit moves ^d				1124			5	5
	Subtotal	599	n/a	2.0	5705	188	49	23	260
CH-53E	AIR-RLT movement ^c	124	3.4	1.7	917	36	16	4	56
	AIR-TF movement ^c	124	3.4	1.8	960	36	16	4	56
	AIR-RES	27	2.3	.9	189	12	6	1	19
	Non-unit moves ^d				411			2	2
	Subtotal	275	n/a	2.0	2477	84	38	11	133

a. Total sorties includes both surge and sustained sorties over a 15-day period.

b. Average sortie rate is the average daily sorties over the first 15 days divided by the number of aircraft needed to fly the sorties.

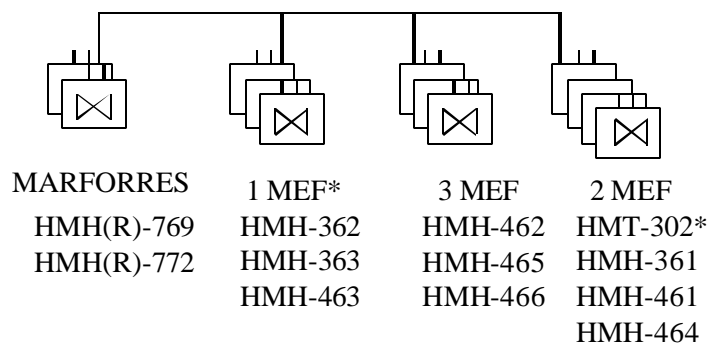
c. Includes ship-to-shore movement and land-based movement of AIR-RLT or AIR-TF.

d. These rows account for additional aircraft sorties and losses for non-unit moves (MAGTF logistics support, reconnaissance insert/extract, and MEDEVAC). Sorties are flown by the same aircraft that fly the unit move sorties.

In the table from the CNA report on the MTW scenario it requires 133 CH-53E's to accomplish the missions. The projected force structure has slated to remove the CH-53E from the reserves and decrease the total number of aircraft to 110. There will not even be 133 CH-53E's in the inventory. The heavy lift mission, unfortunately, is not one that you can simply add more assets of lesser capability and hope to accomplish the mission. It is therefore important to maintain enough assets to ensure we have the required capability when required.

³⁵Center for Naval Analysis, *MARS: Major Theater War Analysis*, August 2001, 47.

Future Task Organization³⁶



- 1 MEF converts its CH-53D's to CH-53E's
- 16 Plane Squadrons

This will provide the Marine Corps the flexibility to meet the peacetime requirements with the units on that particular geographic coast. The squadrons on Hawaii would cover the UDP and the 31st MEU, while the East and West Coast squadrons would support the six MEU deployments, three on each coast. The training squadron could be placed on either coast, wherever adequate training areas and facilities could be maintained.

In the event of a MTW requiring the assets from more than one coast, the reserves would be able to be activated to meet the requirements on that particular geographic coast, if necessary. The remaining active duty squadrons could be embarked to the MTW as required. This would provide a mirror capability on both coasts, and allow a reduced support and training effort to still be conducted on the coast not involved in the MTW.

³⁶ These are the authors suggestions and are not intended to indicate what squadrons remain in any geographic location.

One of the problems is the lack of quantifiable data on the lift requirements.

Numerous studies have been accomplished with assumptions made to validate the procurement of the MV-22. Parameters in the various studies are set up to indicate the Marine Corps will not be able to accomplish its mission, as effectively without the MV-22 and that it is the most cost effective alternative. This paper is not going to doubt the requirement for the MV-22; however, it will challenge the force ratio of 3:1 medium to heavy lift aircraft.

Future Force 1:1 Ratio CH-53E

WAVE	Time		PAX		VEH	MV-22		CH-53E		SORTIES	
	22	53	MV-22	CH-53E		INT	EXT	INT	EXT	MV-22	CH-53E
1	1+07	1+49	1344	448	56	56	0	0	56	56	56
2	1+07	1+49	1344	448	56	56	0	0	56	56	56
3	1+30	1+29	0	0	112	0	56	0	56	56	56
4	1+10	0	0	0	1	0	23	0	0	23	0
TOTAL	4+54	5+07	2688	896						191	168
			3584		225	112	79		191	359	
Maintain the number of airframes required to accomplish the mission at 112. Aircraft availability remains the same for the aircraft .80=70 MV-22's and .70=80 CH-53E's required. Doesn't take attrition of aircraft into account. CH-53E has the ability to carry 8 personnel per external weight of 11,332 pound with a total lift capability of 13,500 pounds for 85NM radius.											

This table is representative of what was conducted by CNA in the MARS. The difference is in the ratio of medium to heavy lift aircraft. We have taken the same total number of aircraft 112 and evenly divided them between MV-22's and CH-53E's.³⁷ The result was a decrease in total sorties required by seven percent and a decrease of eight percent for the MV-22 external sorties. The greatest savings was in the time required to complete the mission. There was a 25 percent savings in time with the equal number of medium to heavy lift assets. The last wave could have been accomplished by the CH-53E's. Due to the time

³⁷ In the MARS they used the current 3:1 ratio of 76 MV-22's to 36 CH-53E's

required, however, it shows a better use of assets to have the MV-22 accomplish the last wave of externals.

Future Force 1:1 Ratio CH-53X

	PAX		VEH	MV-22		CH-53X		SORTIES	
WAVE	MV-22	CH-53X		INT	EXT	INT	EXT	MV-22	CH-53X
1	1344	1344	112	56	0	0	56	56	56
2	1344	0	112	56	0	0	56	56	56
3	0	0	56	0	56	0	56	56	0
TOTAL	2688	1344		0	0	0	0	168	112
	4032		280	112	56	0	168	280	

With the balanced force and the addition of the modernized CH-53E, we see drastic improvements in the capability of the force. There was a 28 percent decrease in sorties required to accomplish the mission and an overall 29 percent timesavings, the difference between 5+07 and 3+38 hours, to accomplish the mission.

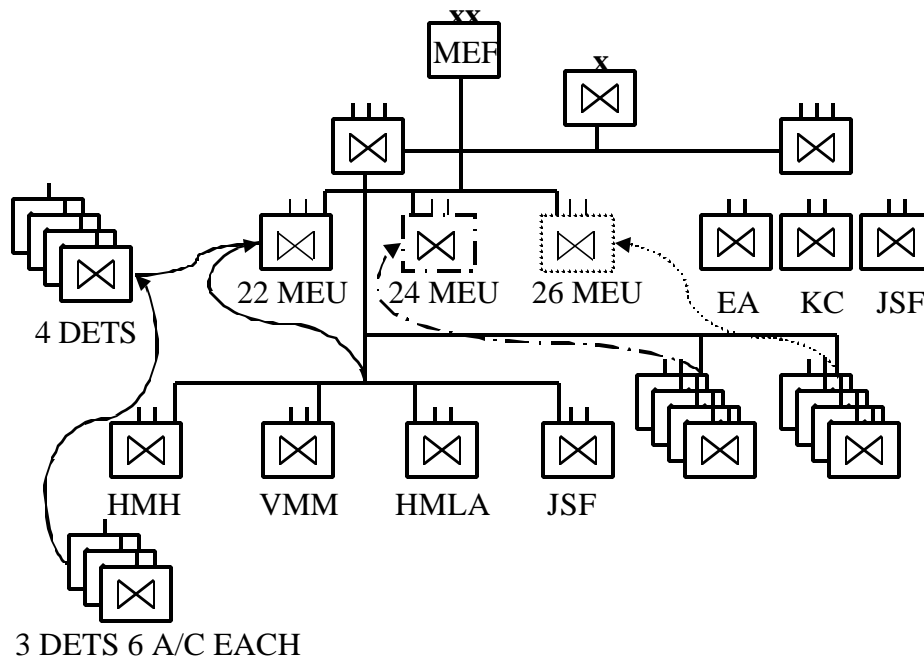
The CH-53E SLEP or modernized CH-53 will be able to accomplish 3.3 MV-22 sorties. The CH-53E could potentially carry in the same sortie two HMMWV's (representing two MV-22 sorties), a MV-22 stick of 24 personnel (representing one MV-22 sortie), and another 8-man stick (representing 1/3 of a MV-22 sortie). By that reckoning, a CH-53E SLEP is equivalent in lift to 3 1/3 MV-22 sorties; the only deficiency is in speed. The capability of 2.3 MV-22 sorties (32 Marines and 1 HMMWV) per CH-53E sortie exists today but only under ideal ambient conditions.³⁸

The benefit of enhancing the CH-53E's capabilities is not just the gain of an additional MV-22 sortie under ideal conditions but under all ambient conditions per CH-53E sortie. This ability is truly a force multiplier as any savings in sorties has a direct correlation

³⁸ Ambient Conditions are defined as the temperature and pressure altitude in which the lift is to be accomplished. The temperature and pressure altitude have an inverse relationship with an aircraft's engine's ability to produce the power required to accomplish the lift. Increases in temperature and pressure altitude equal a decreased payload that can be lifted.

on survivability of aircraft and equipment due to less exposure. But more importantly, it is a savings in the lives of the aircrew and the Marines in the aircraft.

Possible Total Force Structure



This represents a way the force could be organized using the east coast model as an example. The Assault Support Group would be comprised of 9-12 squadrons (Joint Strike Fighter (JSF) dependent). Each group of three to four squadrons (one of each type, model, and series) associated with its deploying unit, the MEU.

The squadrons would be set up to have a total of three detachments. They would differ in experience, the deploying detachment (slated to go on the next MEU) being 100 percent ready for combat. The second detachment would have a slightly decreased readiness value but could effectively employed for combat operations in the event of a contingency or the MEB gets stood up. The MEB ACE could initially be sourced with the contingency detachments from the squadrons in the group. As more assets are required future MEU

detachments as well as entire squadrons could be used. The third detachment would represent the base squadron. This would be where the majority of the instructors and new aircrewmen, mechanics, and technicians would train. This detachment would have the ability to deploy in the event of a MTW or similar contingency requiring every available pilot. The overall readiness would be slightly lower, but they could be effectively used in combat through selectively scheduling (difficult missions would require pairing more experienced pilots and aircrewmen to ensure success). As aircrew become more qualified and experienced as they progress through different stages of training they would then step up as the “leadership” and “experience” in future MEU detachments. This provides the ability to support other contingencies and potentially a MTW without completely decimating the squadron’s ability to train. It also has the intangible benefit of solidifying the operational tempo by forecasting the operational deployments of the individual Marine.

The United States Marine Corps has executed daring long-range raids, evacuations, and rescues on several occasions. Clearly the MV-22 promises to vastly improve the ability to carry out these missions. Historically, such missions have amounted to less than one percent of all missions. The Marine Corps must ensure it is capable of delivering the required effects for a wide range of missions.

There are advocates in the community who have already started to say we need to focus solely on logistics and not the assault support mission of future strategies. The question is what will this look like? The answer is, that the platform will now be called upon to do its heavy lift mission in the most challenging manner, heavy lift at the pace and distance dictated by the MV-22. CH-53E’s in the past have been able to carry significant loads as far as the CH-46E could carry just itself without a payload. The margin of comfort

the CH-53E has been able to perform with in the past will vanish with the successful IOC of the MV-22. The MV-22 will provide the ability to the MAGTF to take the 24 Marines a combat radius of 200 nautical miles without refueling. Therefore, the CH-53E must be able to complete the heavy lift mission to those distances to ensure it is not the limiting factor in the projection or build-up of power.

The CH-53E provides the ability to carry significant payloads great distances over the horizon, without the requirement to have an airfield to land. These attributes are not unique to the CH-53E. What is unique to the CH-53E is that all the attributes are resident in one single platform. The CH-53E provides the ability to aerial refuel from a KC-130 platform with externals and internal loads, extending its range capability to the limitations of the aircrew and the tactical situation.

SLEP

The biggest questions facing the CH-53E right now are whether the Department of the Navy can afford to SLEP the aircraft and what should it encompass? As previously mentioned, there are many competing budget priorities within the Department of the Navy. In the author's view, we must conduct a SLEP of the aircraft if we expect to accomplish Expeditionary Maneuver Warfare. The CH-53E SLEP is truly a transformation enabler for our future concepts, doctrine, and force structure.

The CH-53E SLEP will provide the MAGTF Commander with the ability to complete an artillery raid with the artillery prime mover. These new capabilities will not be based on ideal ambient conditions (cold, sea level) but rather on the harshest conditions (hot, high altitude) we are likely to face. There are several advantages that must be realized when the

CH-53E SLEP is executed to ensure it is as relevant tomorrow as it has been in the past 15 years.

There are seven pillars of the CH-53E SLEP:

- Structural Life Extension (SLE)
- Common Engine (Performance Enhancer)
- Improved Cargo Handling System
- Elastomeric Rotor Head
- Improved Main Rotor Blades (Performance Enhancer)
- Common Cockpit
- Improved Survivability

Although it would be nice to be able to go through and prioritize each of the different aspects of improving the CH-53E, every one of these aspects is vitally important if we are going to use the CH-53E on the modern battlefield.

First, the Structural Life Extension is absolutely required. When an aircraft reaches the airframe time limit of 6120 hours the aircraft must be retired for reaching a structural fatigue life. The areas that require immediate attention are the tail pylon and the cabin area around the main transmission (see figure 5). The first aircraft reached the 6120-hour limit and was retired on the 17th of January 2002. There are an additional 42 aircraft that will be retired by fiscal year 2012 without the SLE (see figures 3&4).

The engines are the next point of the modernization effort of the CH-53E that requires significant attention. The heavy lift mission is accomplished by having the ability to lift a substantial payload. There are two parts of this equation the engines and the transmission. The engines provide the power to drive the transmission. Under the current configuration the aircraft is limited by the engines' ability to produce the required power under all ambient conditions, making the engines are the limiting factor.

The current main transmission has the capability to be powered by significantly stronger engines without requiring any modifications. The stronger engines will be capable of producing greater power over a larger range of ambient conditions (temperatures and altitudes). The engines that are currently being looked at are common among several assault support platforms (MV-22 and the KC-130). This works out to be a win-win for the Marine Corps. Because there is commonality among airframes the unit cost is decreased, parts availability is increased, and the CH-53E gets a stronger engine, which equates to a greater lift capability (see figure 6).

After the aircraft is able to fly with greater lift capability, the next aspect that needs attention is an improved cargo handling system. The CH-53E earns its keep by moving Marines and equipment to and from the battlefield. There are two ways in which this is done, internally (inside the cabin) and externally (under the aircraft). Over the last 20 years there have been 107 unintentional releases of loads that were being carried externally. This has been attributed to several factors, the complexity of the system for both pilots and maintenance personnel and the inability to determine the exact cause of the problem. This problem has led to an overall lack of confidence in the system by both the operators and the people being supported by the external system. It is therefore imperative that the CH-53E gets an external system that is easy to operate and maintain. Moreover this system must, inspire the confidence of the people using the equipment due to its high degree of reliability.

The rotor system is comprised of many components, but one of the most critical is the main rotor head. The main rotor head is comprised of almost 40 individual components, which collectively have the lowest reliability of any major component on the aircraft. This one component contributes significantly to the CH-53Es abhorrent maintenance man-hour

per flight-hour metric in excess of 40 hours (see figure 6). Can you imagine that on average it takes five Marines working a straight eight-hour day in order to fly this aircraft for just one hour (see figure 7)! The main rotor head must be redesigned to capture all the benefits of current technology with an eye toward making this aircraft more reliable and less manpower intensive

The solution is an elastomeric bearing rotor head. The elastomeric bearings are self lubricating, reducing the requirement for a fluid lubricant and the seals necessary to keep it in place. This is a tested and tried solution on the CH-53D and newer rotorcraft. The new rotor system can be designed so that it is fail safe, ensuring that a component failure does not result in a catastrophic aircraft mishap. The overall result will be improved reliability and maintainability while providing a significant reduction in operating costs.

The new improved rotor blades are an enhanced system that is being modeled from current technology. When combined with the greater capability of newer engines the blades alone will account for approximately 5,000 pound increase in gross weight (see figure 8). The new rotor blades will also reduce the maintenance and replacement time due to a greater reliability than the older blades.

The cockpit is perhaps the area, outside of increases in the physical performance of the aircraft, is where the greatest improvements can be made. The importance of an improved cockpit cannot be over emphasized. It has the potential to be common with other assault support assets, reduce pilot workload through integrated complementary systems, increase the survivability of the aircraft through improved situational awareness, significantly increase the mean time between failure by reducing old and/or obsolete avionics components.

In the age of “Full Spectrum Dominance” a platform that plans to operate on the modern and future battlefield cannot afford to be incompatible with future information systems.

The cockpit has the ability to provide an exponential return on the investment by increasing the performance of the aircrew, aircraft and systems ensuring the aircraft is used to its greatest potential. The bottom line is that the cockpit is a critical component in ensuring the relevance of the CH-53E by enabling the ability to maneuver throughout the future battlefield safely and informed of the surrounding environment.

The SLEP survivability improvement initiative is a three-phased approach detection reduction, indications and warnings, and ballistic tolerance. The first step will be to reduce the signature of the aircraft making it harder to detect. This can be accomplished by reducing the infrared or heat signature, radar, and the acoustic signatures of the aircraft.

The second phase will be to provide the aircrew indications and warnings when they have been detected by enemy systems and to either perform the countermeasures in the form of automatic expendable (chaff and flare) use or provide enough warning the aircrew can take appropriate measures.

The final phase is the improvement of ballistic tolerance of the aircraft. In the event the first two phases have not prevented the rounds from impacting the aircraft there are things that can be reinforced and shielded to make the aircraft more survivable and less likely to have the effects of the rounds cause catastrophic failure. In the event the aircraft is hit and is forced to land immediately some of the systems will be designed to improve crash survivability.

Currently the cost of the SLEP is one-fifth the cost of a replacement aircraft. Operationally, it is the most cost effective way to support Expeditionary Maneuver Warfare.

It will provide the Marine Corps with an aircraft that can hover with a 28,000-pound payload on a high/hot day and take 200 nautical miles and return without requiring fuel. The reductions in operations and support cost reduce the flight hour cost by 25 percent of the current cost while providing nearly three times the capability (see figures 6&7).

The problem with the plan is that it is not fully funded and the final objective is to complete only 111 total aircraft. The two reserve CH-53E squadrons along with all the CH-53D squadrons are already slated to transition to the MV-22 around the FY-14/15 timeframe. As previously mentioned we do not currently have enough heavy lift assets let alone reduce the number and hope to be able to accomplish our mission.

SUMMARY

The requirement to carry heavy tactical and logistic equipment dates back to the beginning of warfare. For the modern day helicopter the requirement was derived from concerns on the delays involved in moving unflyable aircraft to repair facilities. In early 1966 the Marine Corps identified an urgent requirement to retrieve downed aircraft and to possess the ability to move heavy, essential combat equipment that exceeded the capability of current helicopters.

The key to the CH-53E's Strategic and Operational relevance is the aircraft's ability to carry out a wide variety of missions critical to both our national interests and prestige as well as service viability. The CH-53E was originally procured to transport 96 percent of the FMF's gear and has become the platform of choice for a wide variety of missions, including many which were formerly medium lift missions. Heavy lift is its own requirement that cannot be accomplished by using more less-capable aircraft. An essential part of the relevance of today's MEU is the CH-53E, due to its "Over the Horizon" capability. This helps to keep the MEU on of every CINC's theater engagement plan.

CURRENT FORCE STRUCTURE

There are several alternatives to make the current force structure more efficient and in doing so increase its effectiveness. When squadrons send out two detachments, as is the case on both East and West Coasts in support of the MEU's, the base squadron is left with approximately 25 percent of the required people to man 50 percent of the assets. This causes an inability to train the base squadron and directly affects the ability to maintain adequately qualified personnel for the follow on detachments and deployments. Therefore a review of current force structure is required.

If we are truly a task-organized force concerned with effects based operations, then we should develop a force structure that is based on the missions we expect to be called upon to accomplish.

MARINE AVIATION REQUIREMENTS STUDY

The study successfully captures the deployment and operational commitments of Marine Aviation. The MARS reports made several assumptions that are questionable:

- The current force structure is correct for the future.
- The baseline metric was the MV-22 fleet
- Limitations imposed on comparison aircraft
- The listed performance parameters were incorrect for the CH-53E

It appeared that instead of truly looking to determine what Marine Aviation requirements will be in the future, it was validating decisions that had already been made with regard to force structure. Using an aircraft that has yet to reach a full rate production decision to base a study to determine the future composition of Marine Aviation appears to be a decision based on a high-risk assumption. A possible deviation to look at might be at having the same number of MV-22, CH-53E, and HMLA squadrons. This would allow the ability to make the ACE a separate command from the medium lift squadron. The Aviation Combat Element has routinely been built around the HMM squadron. There is no other reason than the CH-46 makes-up the preponderance of the forces per the current force structure

The CH-53E currently has the capability to provide 3.55 CH-46E sorties per every CH-53E sortie when looking at cargo (CH-46E carrying 3,800 pounds). The CH-53E has the ability to provide 2.2 sorties when carrying passengers (CH-46E carrying 14 passengers). With these capabilities the current MEU has the ability to project power out to 127 nautical miles with its assault support assets today.

If we were to look at another option of changing the medium lift to heavy lift ratio to 2:1 by increasing the number of CH-53E's (to six) we would see a 20 percent reduction in total waves and a 22 percent decrease in time to accomplish the mission with today's current force augmented by two additional CH-53E's.

FUTURE HEAVY LIFT REQUIREMENTS

The Marine Corps has long tied its ability to accomplish EMW with the MV-22 and the AAV programs. We are replacing the CH-46 and the AAV with vehicles that have the same or less cabin space respectively. Evidence from the Operation ENDURING FREEDOM suggests Marines and soldiers are carrying larger than normal quantities of gear and equipment. There is a common misconception that the forces of the future are getting lighter, while in fact they are getting heavier.

While conducting externals the MV-22 experiences a decrease in speed and loses its ability to aerial refuel. Future projections have the MV-22 carrying externals for 48 percent of its sorties in the movement of a Regimental Landing Team (RLT). The best alternative to having the MV-22 lose its speed advantage is to ensure there are enough CH-53E's to maximize the MV-22's potential. The only way to truly realize the full potential of the MV-22 is to ensure we have the synergistic relationship between the medium and heavy lift aircraft working together to accomplish the mission.

The projected force structure is not capable of supporting these concepts without 100 percent utilization of all of the CH-53E assets currently in the inventory. The projected force structure has slated to remove the CH-53E from the reserves and decrease the total number to 111. The heavy lift mission, unfortunately, is not one that you can simply add more assets of lesser capability and hope to accomplish the mission.

FUTURE TASK ORGANIZATION

Reorganizing the current force structure will provide the Marine Corps the ability to meet the peacetime requirements with the units on that particular geographic coast and the flexibility to take assets during wartime from the other coasts to meet the requirement. A possible solution is that the squadrons on Hawaii would cover the UDP and the 31st MEU, while the East and West Coast squadrons would support the six MEU's (three on each coast).

FUTURE FORCE 1:1 RATIO MV-22 TO CH-53E

There is a significant savings associated with balancing the force. By using the same total number of aircraft 112 and evenly dividing them between MV-22's and CH-53E's the result was a decrease in total sorties required by seven percent and a decrease by eight percent for the MV-22 external sorties a 25 percent savings in time.

FUTURE FORCE 1:1 RATIO MV-22 TO CH-53X

The CH-53E (SLEP) provided a significant improvement in the movement of the force. There was a 28 percent decrease in sorties required to accomplish the mission. The overall timesavings were 29 percent in addition to the already realized savings of 25 percent from balancing the force with today's CH-53E.

The CH-53E SLEP or modernized CH-53 will be able to accomplish 3.3 MV-22 sorties for every CH-53 sortie. The CH-53E could potentially carry two HMMWV's (representing two MV-22 sorties), a MV-22 stick of 24 personnel (representing one MV-22 sortie), and another 8-man stick (representing 1/3 of a MV-22 sortie. This ability is truly a force multiplier as any savings in sorties has a direct correlation on survivability of aircraft and equipment due to less exposure.

The future for the CH-53E will be challenging, it will now be called upon to do its mission in the most challenging manner, heavy lift mission but at the pace and distance dictated by the MV-22.

SLEP

These new capabilities will not be based on ideal ambient conditions but rather on the harshest conditions we are likely to face high altitudes, hot temperatures, and heavy gross weights. There are seven pillars of the SLEP that are commonly addressed are as follows:

- Structural Life Extension
- Common Engine (Performance Enhancer)
- Improved Cargo Handling System
- Elastomeric Rotor Head
- Improved Main Rotor Blades (Performance Enhancer)
- Common Cockpit
- Improved Survivability

The Structural Life Extension (SLE) is absolutely required because when the airframe reaches its time limit of 6120 hours the aircraft is required to be retired until it can be reworked. The first aircraft was retired on 17 January 2002. There are an additional 42 aircraft that will be retired by fiscal year 2012 without the SLEP.

The cost of the SLEP is one-fifth the cost of a replacement aircraft. Operationally it is the most cost effective way to support Expeditionary Maneuver Warfare. The reductions in operations and support cost reduce the flight hour cost by 25 percent of the current cost while providing nearly three times the capability.

The problem with the current plan is that it is not fully funded and the final objective is to only SLEP 111 aircraft. The two reserve CH-53E squadrons along with all the CH-53D squadrons are already slated to transition to the MV-22 around the FY-14/15 timeframe. As

previously mentioned we do not currently have enough heavy lift assets let alone reduce the number and hope to be able to accomplish the heavy lift mission.

Thirty years ago the Marine Corps identified the lack of heavy lift as being “the single most critical shortfall in the Fleet Marine Force inventory” during combat operations in the Vietnam Conflict. Today with our recent experience in Afghanistan and the resultant increase in the operational tempo of heavy lift squadrons. The question must be posed, what have we done to maintain or enhance this capability over the last thirty years? We have done the absolute minimum to maintain or enhance this capability. Numerous studies have indicated that heavy lift is critical to the success of future concepts of employment, but we have made little progress in determining where heavy lift is going in the future.³⁹ We have retired the first aircraft and there is no replacement in sight!

What is needed now is a study aimed at determining what capabilities are required in the near future for the CH-53E SLEP and what will be the required capabilities of the follow on aircraft. From this point it can be logically assumed that the correct number of these aircraft can be determined to fulfill the requirements. The final piece of the study should address the transition plan of how to get there from here.

³⁹ The CNA MARS stated that the CH-53E is required to accomplish the heavy lift mission that the MV-22 cannot accomplish. MAWTS-1 conducted an OMFTS Working Group and determined the CH-53E was absolutely essential in the successful employment of the MEB in 2010.

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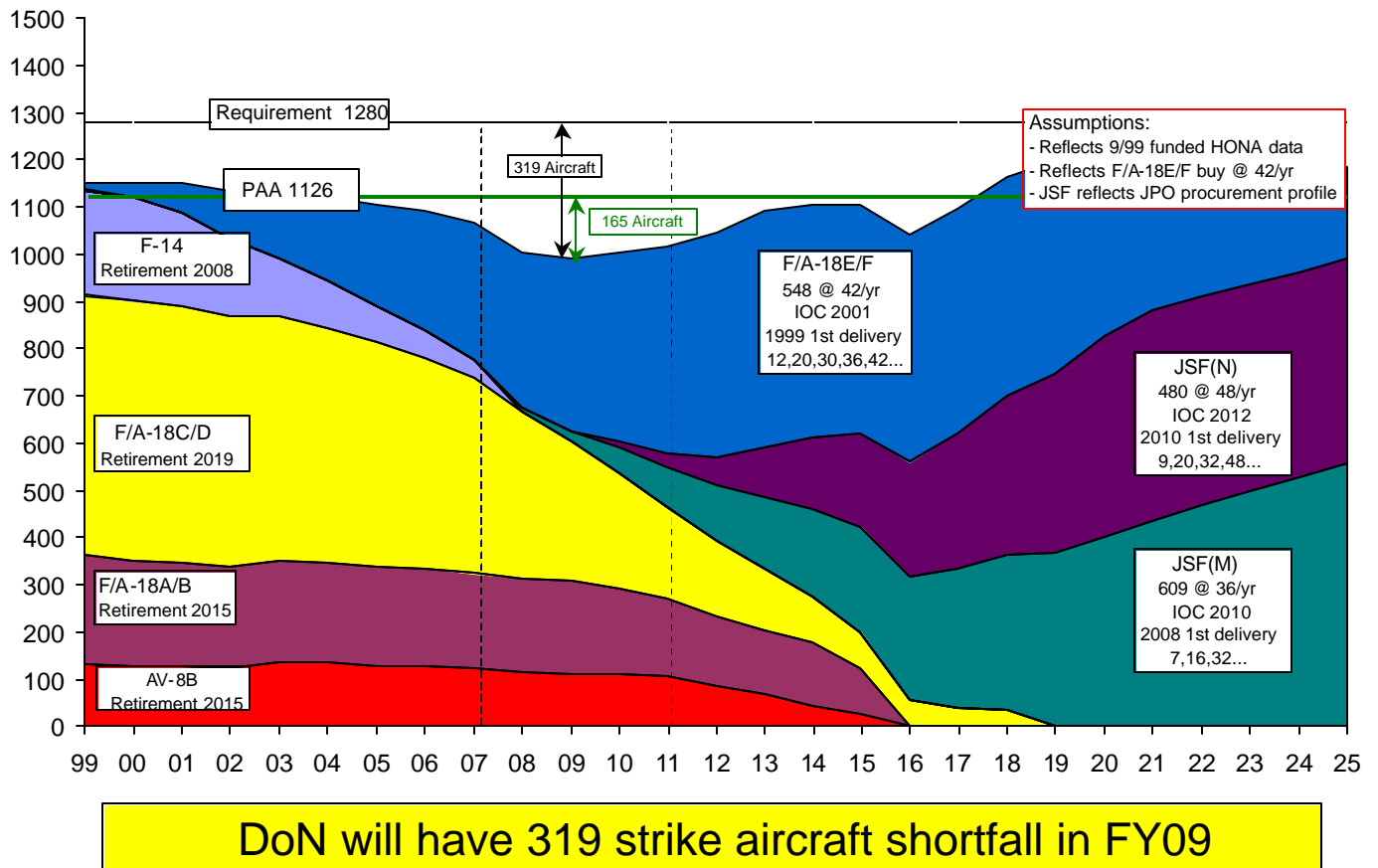
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FIGURES

Figure 1⁴⁰

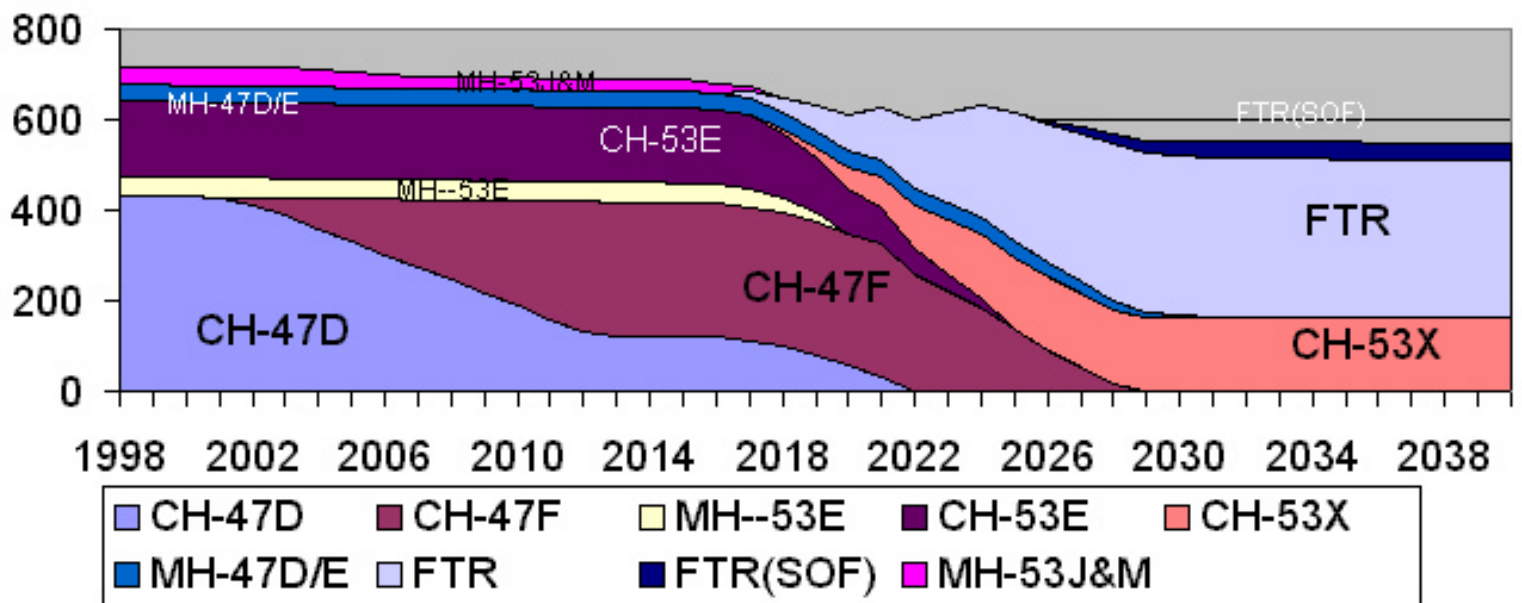
DON Inventory



⁴⁰ DoN Strike Aircraft Shortfall, N.P., N.D. Received from APW-51, Major John Celigoy. February 2002.

Figure 2⁴¹

Service Projected Heavy Lift Inventory



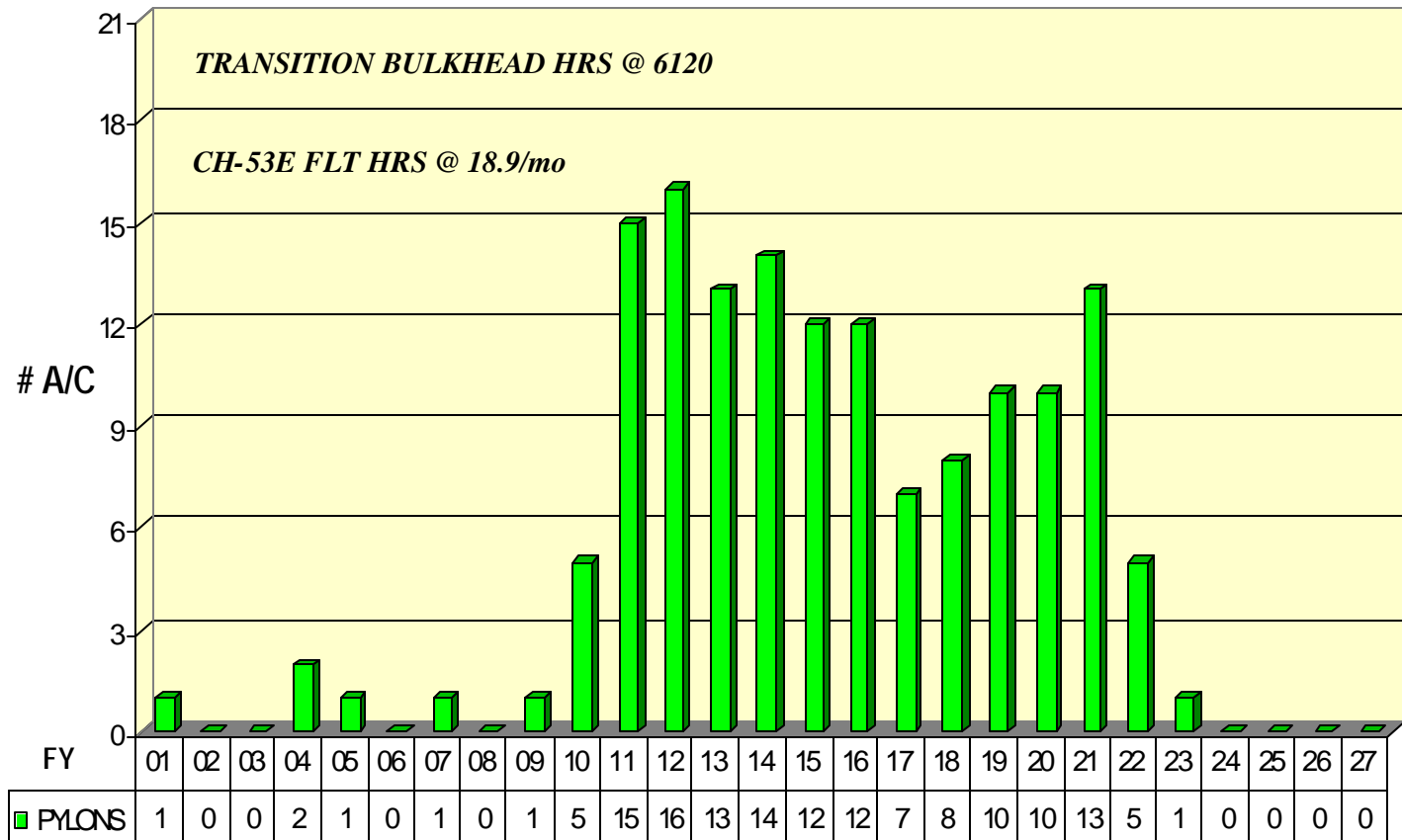
Apr-02

⁴¹ Usry, Floyd, LtCol USMC. Overarching Rotorcraft Commonality Assessment (ORCA), CH-53E Program History, N.P., N.D. Received from APW-51, Major John Celigoy, 12 April 2001, 14.

Figure 3⁴²

CH-53E Retirement Schedule

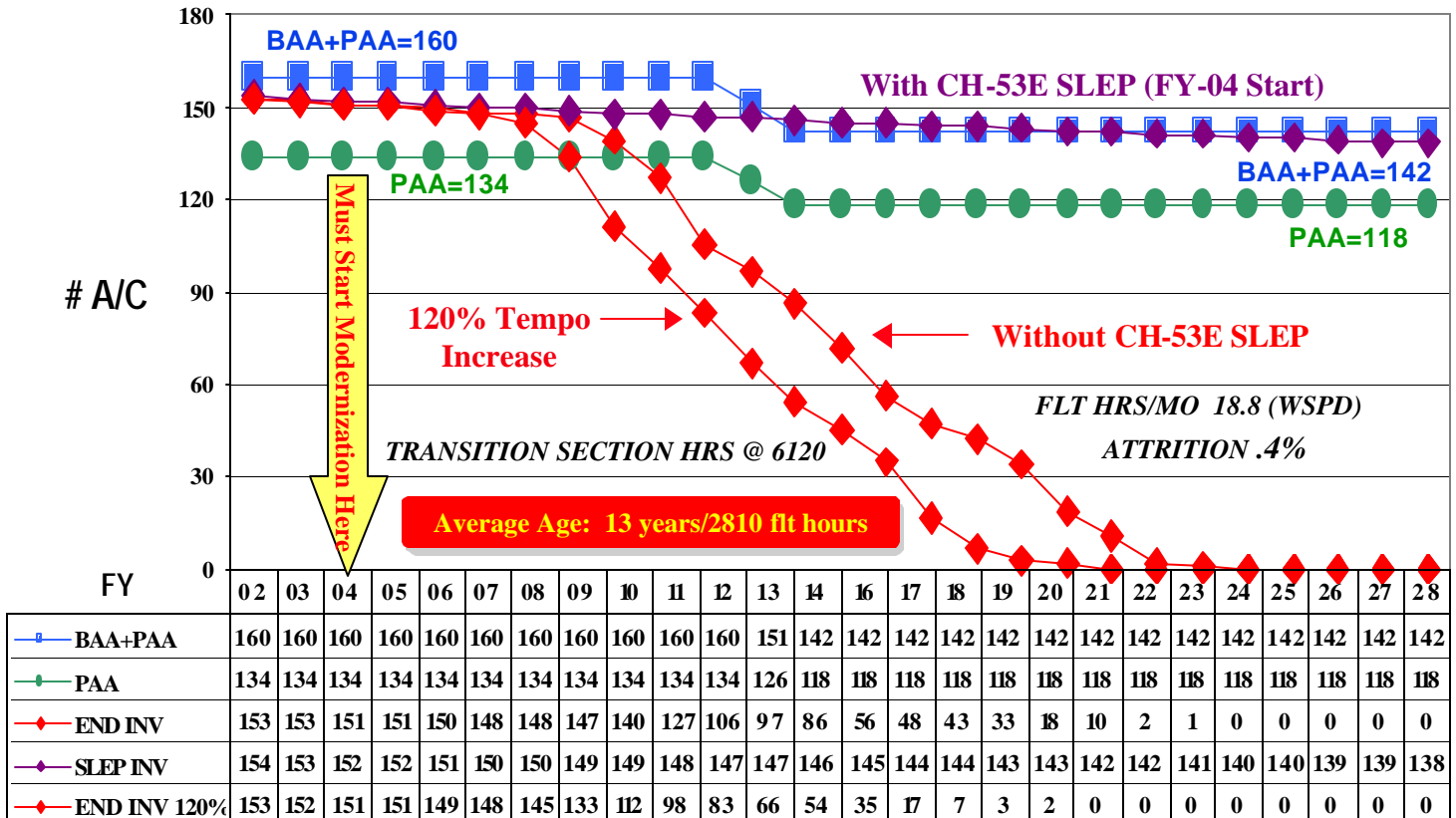
(Based Upon Fatigue Life Limits)



⁴² Haberbosch C. LtCol USMC, *CH-53E Modernization Program: An Affordable Solution to Heavylift*, Brief to the Marine Air Board given 17 April 2001, received from Maj Celigoy APW-51, January 2001.

Figure 4⁴³

CH-53E FLEET INVENTORY FATIGUE / ATTRITION



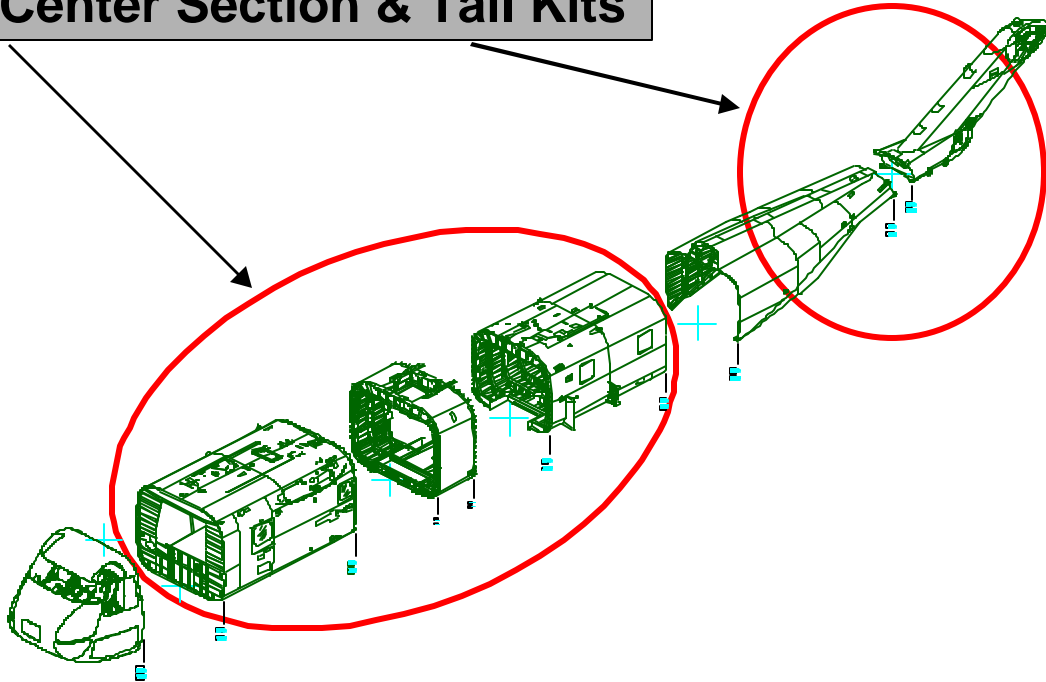
Data Current as of 31 AUG 01

⁴³ CH-53E Retirement Waterfall Chart, N.P., N.D. Received from APW-51, Major John Celigoy. November 2001

Figure 5⁴⁴

Service Life Extension Approach

**Manufacture New
Cabin Center Section & Tail Kits**



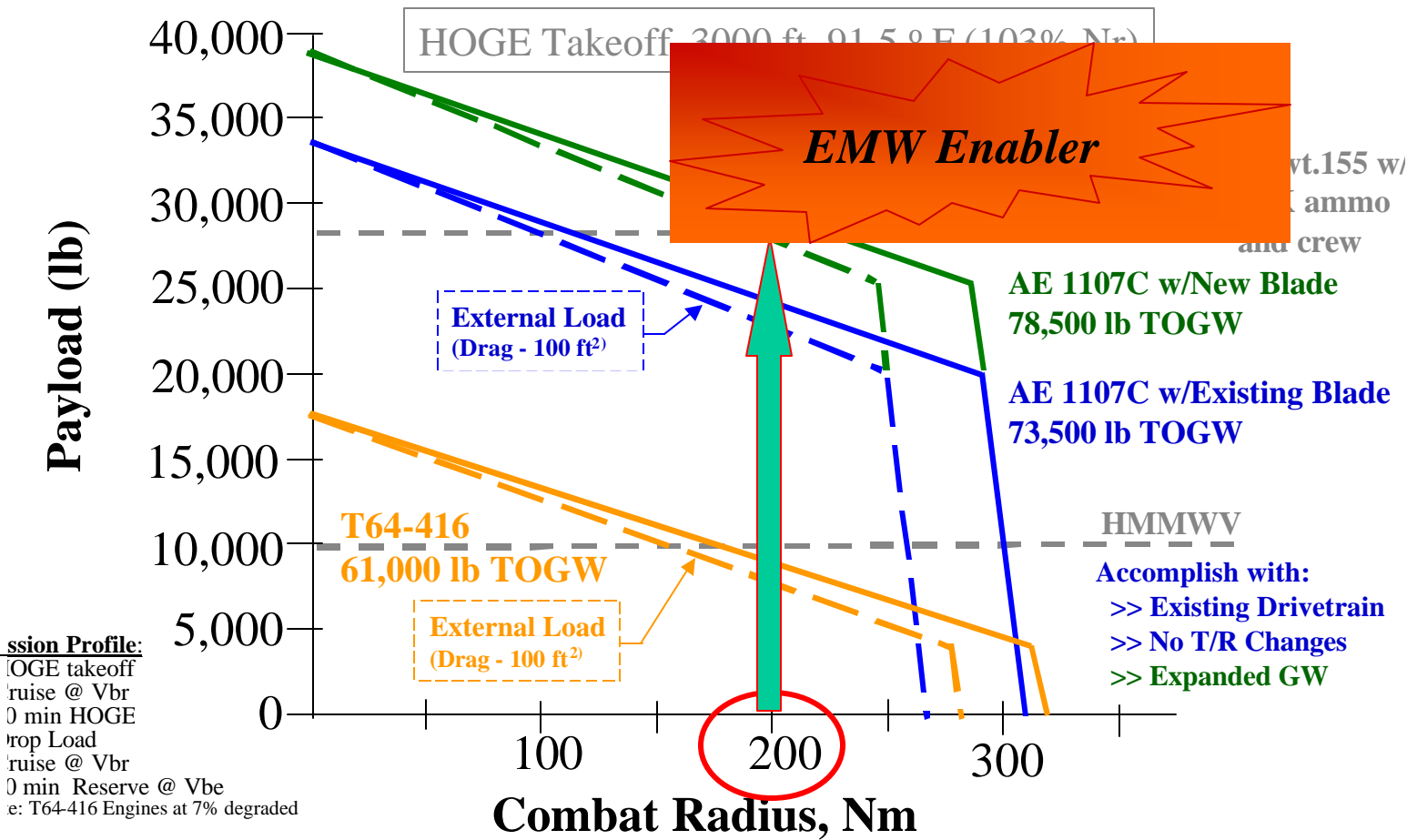
Replace Kapton Wiring

⁴⁴ Haberbosch C. LtCol USMC, *CH-53E Modernization Program: An Affordable Solution to Heavylift*, Brief to the Marine Air Board given 17 April 2001, received from Maj Celigoy APW-51, November 2001.

Figure 6⁴⁵

AE1107C Engine & New Blade

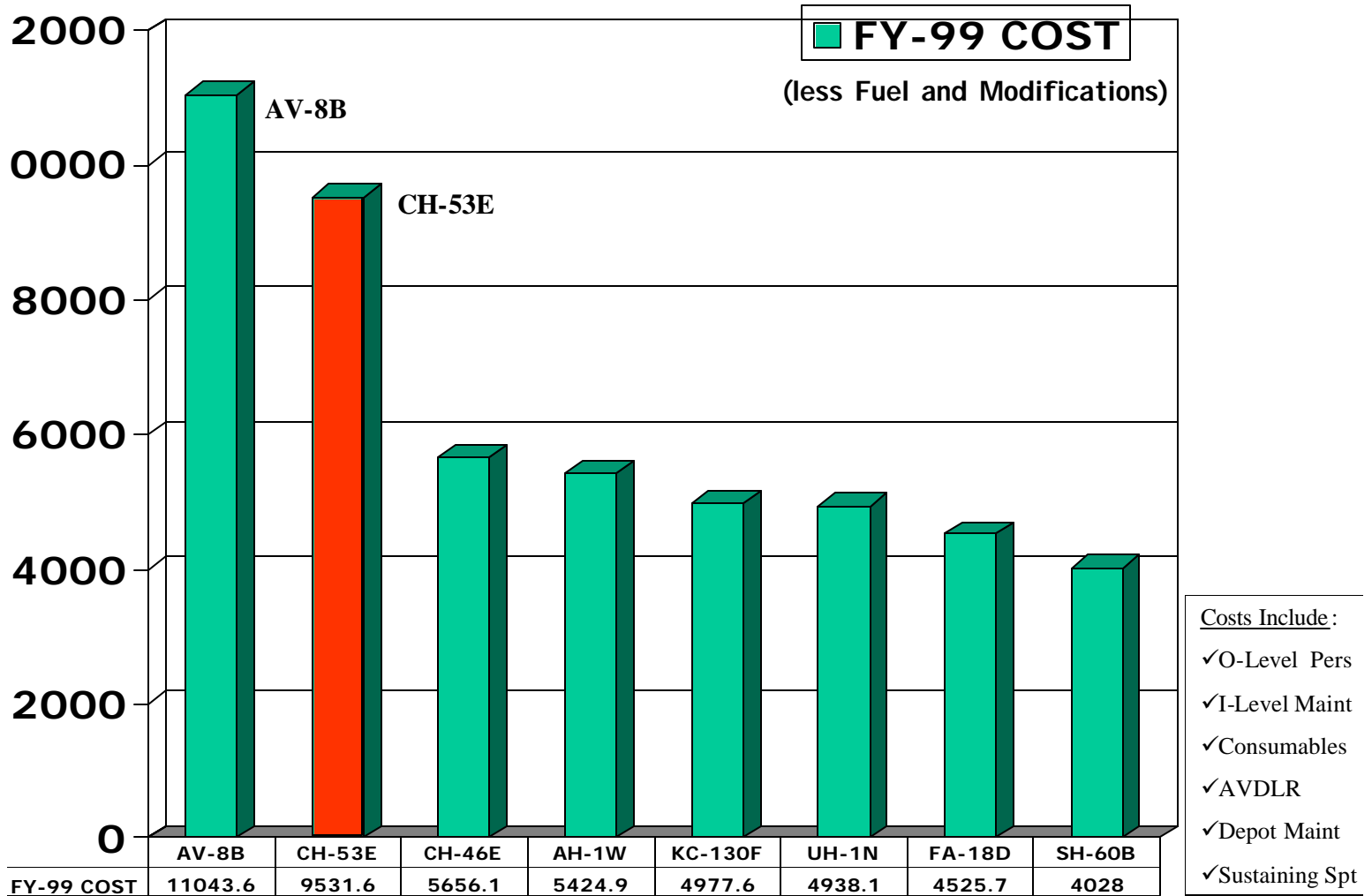
Enables Hot/High 28K Payload



⁴⁵ Haberbosch C. LtCol USMC, *CH-53E Modernization Program: An Affordable Solution to Heavylift*, Brief to the Marine Air Board given 17 April 2001, received from Maj Celigoy APW-51, November 2001.

Figure 7⁴⁶

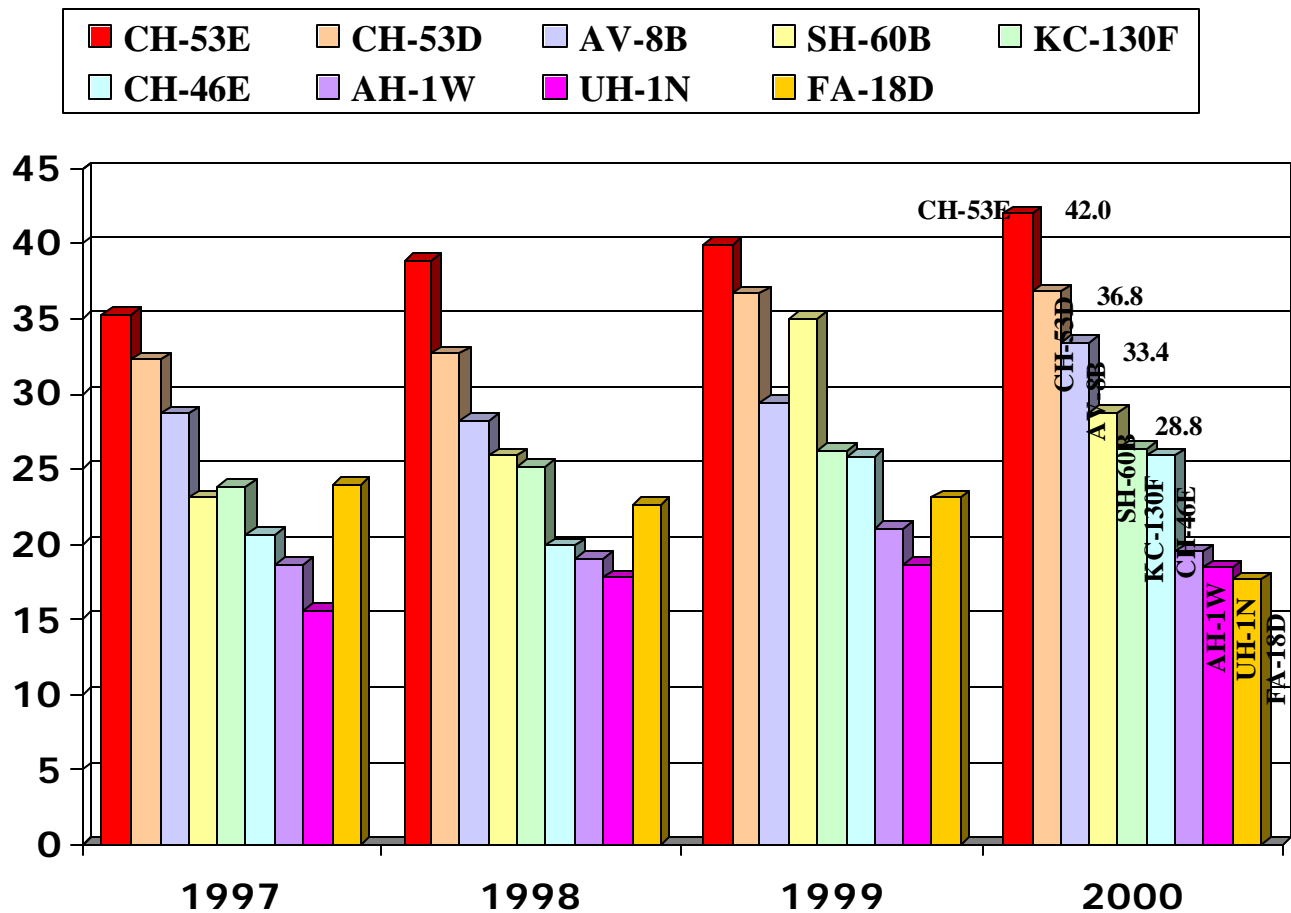
Cost Per Flight Hour



⁴⁶ Haberbosch C. LtCol USMC, *CH-53E Modernization Program: An Affordable Solution to Heavylift*, Brief to the Marine Air Board given 17 April 2001, received from Maj Celigoy APW-51, November 2001.

Figure 8⁴⁷

DMMH per Flight Hour



Source: AV-3M Report 4079

⁴⁷ Haberbosch C. LtCol USMC, *CH-53E Modernization Program: An Affordable Solution to Heavylift*, Brief to the Marine Air Board given 17 April 2001, received from Maj Celigoy APW-51, November 2001.